

AD/A-007 072

**AN OPERATIONAL FIRE HAZARDS ANALYSIS
OF THE C-5**

Air Force Logistics Command

Prepared for:

**Air Force Systems Command
Military Airlift Command
Lockheed-Georgia Company**

February 1975

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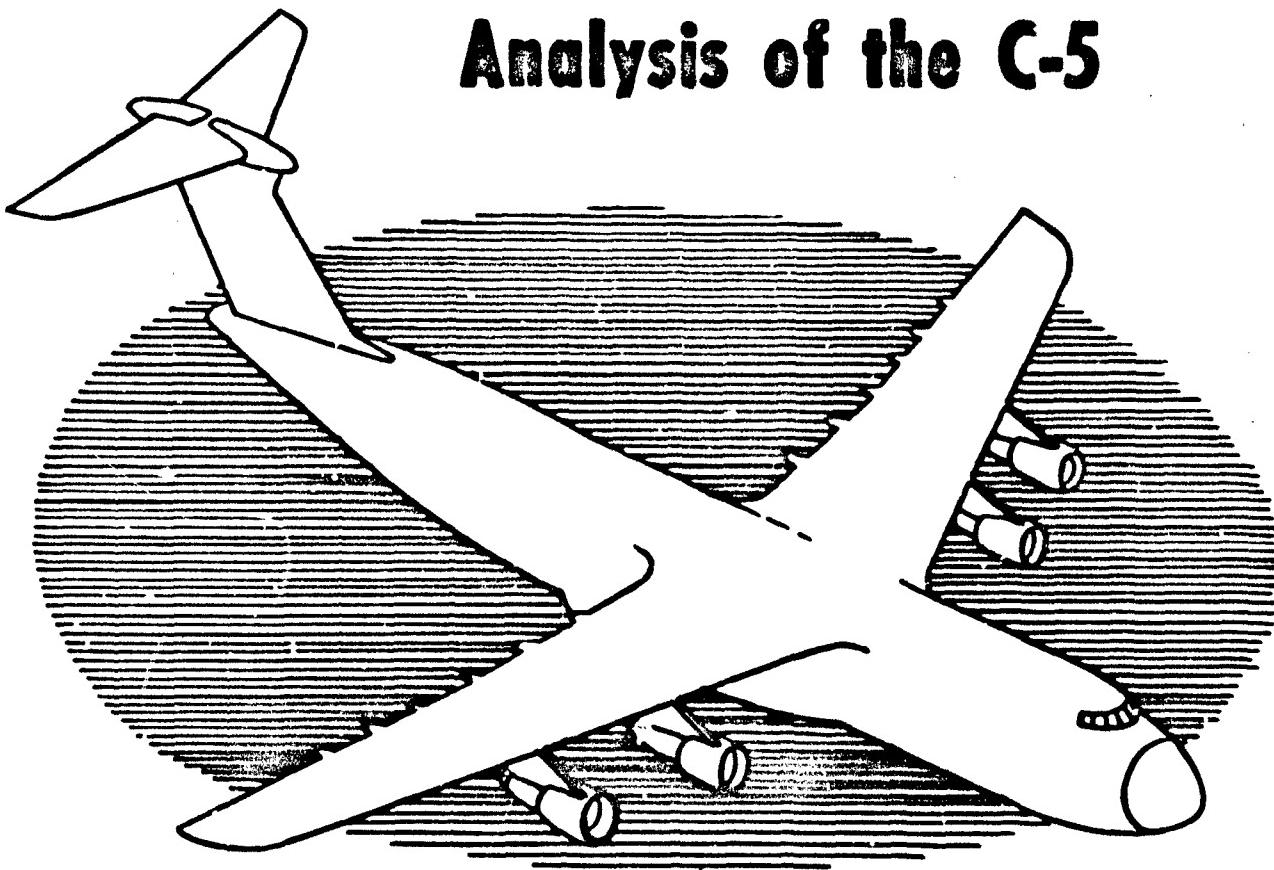
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FIRE HAZARDS STUDY

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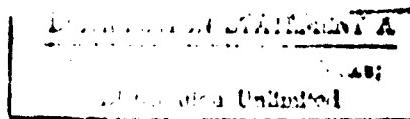


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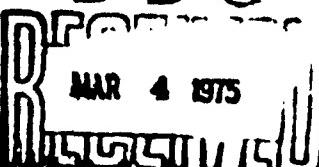
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C-5 FIRE HAZARDS STUDY

**An Operational Fire Hazards
Analysis of the C-5**

CONDUCTED BY: **AFLC**
MAC
AFSC
LOCKHEED

FEBRUARY 1975

REPORT
C - 5 FIRE HAZARDS STUDY

February 1975

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FOREWORD

As a result of the fire initiated accident on C-5 S/N 68-0227 at Clinton, Oklahoma, in September 1974, Military Airlift Command (MAC) requested that Air Force Logistics Command (AFLC) host an Air Force study group to investigate the potential of hydraulic fire on the C-5. The study was to cover the complete aircraft and all possible ignition sources, with ignition resulting either from normal operating temperatures or from malfunction of components. The scope was later expanded to include consideration of all possible combustibles.

The study group convened for its first meeting at San Antonio ALC in December 1974, with representatives from MAC, Aeronautical Systems Division (ASD), Lockheed Georgia Company, and San Antonio ALC. Objectives and methods were discussed. Specific research requirements were determined and assigned. Following completion of the background research, the group reconvened at San Antonio ALC January 1975 to identify potential hazards and accomplish an onboard examination of each hazard location.

ABSTRACT

This report was prepared as a result of a MAC request for an investigation of C-5 hydraulic systems and potential ignition sources. The study was expanded to include other combustibles in addition to hydraulic fluid. The report provides description of the types of combustibles and ignition sources considered and the characteristics necessary for ignition. Sections of the report describe the areas examined; the areas presently covered by protection systems and to be covered by the Fire Suppression System; and the specific fire/explosion hazards identified. None of the hazards identified require restriction of flight operations pending correction. Two hazards were identified which are of sufficient fire/explosion potential that corrective actions should be expedited; and 24 other hazards for which corrective actions are recommended. Most of the hazards are not unique to the C-5.

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INTRODUCTION

I. OBJECTIVE

The objective established for the study group was to identify potential fire hazards in the C-5. A potential fire hazard may be identified as any area containing both an ignition source and a combustible material. The C-5, as any aircraft, contains the combustibles (such as hydraulic fluid and JP-4) and ignition sources (such as electrical/electronic components and wiring; hot surfaces; hydraulic motors, actuators, and highspeed rotating components) necessary for fire initiation, i.e., potential fire hazards. However, in many cases, the potential ignition sources are so well protected (e.g., explosion proof motors, circuit breakers), and the possibility of a combustible in the right conditions is so remote that the likelihood of both events occurring concurrently is considered minimal. Therefore, the objective for the study was further defined as identification of those areas where both the combustible and the potential ignition source are located, where one or both of the necessary events (available combustible, ignition temperature) are known to have occurred or are considered probable, and, thus, when there is a greater likelihood of fire over the lifetime of the C-5 aircraft. Greatest emphasis was placed on identifying those hazards that could initiate a fire where the probability of detection would be negligible.

II. ASSUMPTIONS

The study is based on the following assumptions:

- a. That hydraulic or JP-4 lines will leak or rupture, i.e., that these fails will be present at some time in any area where the lines are routed.

- b. That shorting, arcing and overheating will occur at some time in any electrical wiring.
- c. That the Fire Suppression System (FSS), as presently configured, will be installed. However, all potential hazard areas were evaluated as to seriousness both prior to installation of FSS and with the system installed.

III. METHOD

The method used for the study involved four steps:

- a. Identify the potential combustible materials and types of ignition sources and define the characteristics necessary for ignition.
- b. Identify the specific areas in which both combustibles and potential ignition sources are located.
- c. Examine these areas and evaluate specific components to verify the existence of an ignition source and the presence of a combustible which could come in contact with that source. Analyze these areas considering the presence/absence of fire/overheat detection and suppression.
- d. For those hazard areas identified, determine the action necessary to reduce or eliminate the hazard. This may be a procedural requirement or a modification.

This report provides a general discussion of the areas considered and the hazards identified. Details of each item, component, and area examined, and complete analysis of its hazard potential may be found in the Operational Fire Hazard Worksheets, Appendix E.

DISCUSSION

I. DEFINITION OF FIRE HAZARD

In order to identify the fire hazards in the aircraft, it was first necessary to define the elements and conditions required for fire initiation. Three elements are necessary: a combustible, an oxidizer, and an ignition source. A complete discussion of combustibles and ignition sources, their characteristics, and the conditions necessary for ignition is provided in Appendix A. A brief summary is provided here:

- a. Combustibles - Among the potentially combustible materials on the C-5 are JP-4, hydraulic fluid, nonmetallic materials (insulation, fabric, panels, etc), and combustible cargo. However, investigation of the nonmetallic materials revealed them to be flame resistant, self extinguishing or slow burning and, therefore, of minor concern as combustibles, or fuels, for a fire. Additional information on C-5 materials and their fire resistant characteristics may be found in Appendix B, Nonmetallic Materials; Appendix C, Blend Air Duct Test; and Appendix D, C-5 Wiring. The most common combustibles on aircraft are JP-4 and hydraulic fluid. These, along with combustible cargo, will be the primary combustibles considered in this study.
- b. Oxidizer - Oxygen, either from the air or from the aircraft oxygen system, provides the oxidizing agent.
- c. Ignition sources - These can be electrical arc, sparks, high temperatures, etc.

It should be emphasized that just the presence of the three elements does not constitute a fire. Combustion is dependent on several factors. For example, when considering such materials as JP-4 and hydraulic fluid, these factors include the ignition energy, the temperature of the combustible and the air, and the combustible - air mixture (i.e., vapor ratio). The specific range in which each of these physical properties exists determines its contribution to the ignition sequence. These factors were considered in evaluating the fire potential of each area.

II HAZARD IDENTIFICATION

The process of identifying the C-5 hazards involved determining the specific areas to be investigated, examining those areas for likelihood of ignition, and evaluating the protection available or to be provided. Availability of protection was not grounds for ignoring a potential hazard. But, if a hazard was considered to exist, protection was a factor in evaluating the seriousness of the hazard.

A. Areas considered:

Considering the elements necessary for fire, the study group compiled a list of items that are considered potential sources of ignition and are located near a combustible material. The list included any electrical/electronic component, hot surface, hydraulic motor, actuator or high-speed rotating component that could provide a source for ignition. Each item was evaluated and inspected on the aircraft to determine the physical relationship of the combustible and ignition source, and the likelihood of a fire occurring. The areas of the aircraft investigated included pressurized and unpressurized compartments of the fuselage, wings, and empennage. Worksheets identifying each component/area examined, describing the hazards identified, and specifying recommendations for correction of the hazards are provided in Appendix E.

B. Present Aircraft Fire Protection Systems

Detection systems are presently installed in the engine and APU compartments. The system will detect fires and overheat in the engine pylon and fires in the APU compartments. The C-5 has three complete extinguishing systems, one for the two left engines, one for the two right engines, and one for the two auxiliary power units. Each engine system consists of two containers, charged with dibromodifluoromethane (DB) and pressurized with nitrogen, located in inboard pylons. The system provides the capability for one discharge to each nacelle or for both discharges to one nacelle. Each container is charged with 7.5 pounds of agent. This quantity of agent is considered sufficient to extinguish fires in the engine compartment. Statham analyzer tests have confirmed adequate agent concentration, distribution and duration.

The APU compartments are protected by a High Rate of Discharge (HRD) type fire extinguishing system. The system consists of two containers, each charged with 4.5 pounds of dibromodifluoromethane. The system provides the capability for one container to discharge to each compartment or for both containers to discharge to either compartment. Statham analyzer test on the APU/ATM installation verified adequate concentration, distribution and duration.

Detection systems are used to monitor bleed air ducts throughout the aircraft. The wing detection system consists of continuous type heat sensing loops which detect excessive temperature in the vicinity of the bleed air duct couplings in the right and left wing leading edges, pylons,

air conditioning compartment and under the floor on the heat ducting. When the system alarms, an automatic shutdown of that portion of the bleed air system is initiated. This involves closing valves to stop flow in that portion of the system where a leak was detected and illuminating the overheat warning lights on the flight engineer's panel.

In the occupied areas it is expected that fire normally will be detected by personnel in the aircraft. Smoke or odors from fires will be sensed by personnel in the vicinity. Smoke detectors are installed in the cargo, avionics, AC load center and troop compartments to sense the occurrence of the type of fire or overheat condition that generates smoke. A total of twelve (12) portable, type A-20 fire extinguishers are available for fire fighting and are installed in the flight station, relief crew quarters, courier area, troop compartment and the cargo compartment.

C. Fire Suppression System (FSS)

A detailed description of the FSS installation and operation is provided as Appendix F. It also provides rationale regarding areas not protected. A brief description is provided here.

- 1) The FSS will provide fire detection and inerting or suppression in the following areas of the aircraft:
 - a) Fuel tanks
 - b) Cargo compartment
 - c) Avionics and Guidance (A&G) equipment compartment
 - d) The center wing section, including the Environmental Control System (ECS) equipment, wing box and flap control equipment
 - e) The wing dry bays and wing and pylon leading edges

- f) The main and nose wheel wells
 - g) The forward and aft under floor areas
 - h) The Power Transfer Unit (PTU) compartments in the main landing gear pods
- 2) These areas will not be protected by FSS or existing aircraft fire protection systems:
- a) The empennage
 - b) The wing flap and aileron wells
 - c) The main landing gear pod aft of the wheel wells, under the pressure vessel and between the APU compartments
 - d) The underfloor compartments to the left and right of the nose wheel well
 - e) Radome
 - f) Wing tips
 - g) Behind the lower wing fillet fairing and behind the lobe-to-lobe panels
 - h) Wing leading edge outboard of outboard engines

D. Hazards Identified

1) General characteristics

For purposes of this study, a hazard has been defined as an area where both the combustible and the potential ignition source are located, where one or both of the necessary events (available combustible and ignition temperature) are known to have occurred or are considered probable, and thus constitute a greater potential for fire over the lifetime of the C-5 aircraft. From the investigation, 26 specific areas,

components, or items were identified which meet this requirement. The remaining areas were not considered hazards either because the necessary combustible or ignition source was not present, or because the likelihood of malfunction needed to provide one of these elements was too small. The general characteristics of the identified hazards are described below:

- a) With one exception (described in paragraph 2)a)1)), all of the 26 hazards require a minimum of two failures, one to provide a combustible and the second to provide ignition. In most hazard areas the combustible was JP-4 or hydraulic fluid. The most common potential ignition sources were electrical arcing and overheating components.
- b) None of the hazards require restriction of aircraft operations pending correction of the conditions which contribute to the hazard.
- c) Most of the hazards are in areas which will be better protected after FSS installation. This will not eliminate the hazard, i.e., the potential for fire. But it will reduce the probability of serious damage prior to the fire being detected and extinguished.
- d) Although not so serious as to require aircraft grounding for correction, two of the hazards are considered significant because there would be no adequate means of detection or suppression in the area and the occurrence could result in significant aircraft damage. In these cases corrective action should be expedited. The remaining items are considered hazardous because the necessary elements are present and could result in fire over the lifetime of the C-5. They are not considered to be as serious because of the multiple circumstances necessary for the event to occur and because of the limited potential for serious damage prior to detection. The study group has also proposed recommendations for correction of each of these hazards.

e) Seven of the 26 hazards can be reduced to an acceptable level by procedural changes, e.g., T.O. changes, inspections. The remaining 19 items would require modification, or further study to determine the nature of modification, to reduce/eliminate the threat. The necessary modifications or studies are already in progress on seven of these 19 items.

f) Most of the hazards concern items, components, or conditions common to aircraft; therefore, each hazard should be evaluated for applicability to other aircraft.

2) Specific Hazards

The hazards are divided into two groups based on the seriousness of the event if it occurs:

(NOTE: The numbers in parentheses following each hazard refer to the specific hazard worksheet which may be found in Appendix E.)

a) Primary Hazards

1) JP-4 fuel behind the lower wing fillet fairing and behind the lobe-to-lobe panels (1) (hereafter referred to as wing fillet/lobe area). This presents both a fire hazard and an explosion hazard. The fire hazard is dependent on a single failure as JP-4 can exist in the area either from aerial refueling operations or from the Auxiliary Power Unit (APU) fuel line fittings leaking. Then, during ground operation of the APU, the JP-4 can run down the fuselage into the APU inlet or exhaust and be ignited. The explosion hazard requires two modes of failure: the existence of JP-4 in the wing fillet/lobe area, and an ignition source in the same area in the same time frame. The fire hazard is of primary concern because the area will not be protected by FSS. Although a fire would be immediately detected by personnel operating the APU, serious damage could occur before it could

be extinguished. The explosion hazard is not considered to be as serious because, in addition to the need for multiple malfunctions, the damage would likely be limited to blowing off the fairings and lobe panels.

(2) Explosive JP-4 mixture can collect in the wing dry bays (2) and be ignited by damaged electrical wiring. Even though requiring two failures, this hazard is of major concern because of the probable consequences of such an explosion.

b) Secondary Hazards

The areas described herein are considered hazards because the possibility does exist for fire to occur at some time during the life span of the C-5, i.e., the necessary elements are present. However, these hazards are not considered to be as serious because of the need for multiple malfunctions, and because the probability of detection is greater. These 24 hazards are in the following general areas:

(1) The fire hazard caused by fuel leaking from a failed aerial refueling system manifold onto the Flight Engineer's panel (3).

(2) The potential for wiring problems and resultant ignition hazard exists in several areas: the use of aluminum wiring; and missing or deteriorated wiring feed-through grommets (4), leaking JP-4 flowing onto landing light wiring (5), and clamp deterioration (6).

(3) Engine and pylon problem areas include vapor barrier deterioration and lack of air circulation on engine right side (7), engine driven hydraulic pump rupture (8), and engine/pylon bleed air duct seal deterioration (9).

(4) Two types of components, the flap power pack (10) and the three power transfer units (11) (12), were found to have known

failure problems that can result in loss of large quantities of hydraulic fluid, providing a combustible that can spread to ignition sources outside the immediate areas.

(5) Aircraft batteries (13) were identified as hazardous for two reasons. Small hydrogen gas explosions are known to occur within the batteries due to the charging cycle. In addition, under some conditions, the batteries will fail to fire the FSS.

(6) The chine drain system (14) was determined to provide a source of some hydraulic fluid that constitutes a hazard within the main landing gear wheel wells.

(7) The emergency generator (15) was determined to represent an ignition hazard in the event of contactor failures.

(8) The crosswind computer (16) can serve as an ignition source if the printed circuit cards reach excessive operating temperatures.

(9) An unusual hazard is presented by the troop compartment grill (17) due to the ease with which a cigarette could be dropped through it onto cargo loads.

(10) Several components were found to constitute some hazard due to failure modes which might generate ignition temperature. These include, but are not limited to: landing gear extend/retract system (18); tires and brakes (19); underfloor heat fans (20); wing bleed air isolation valves (21); and the slot proximity control box (22).

(11) The forward and aft underfloor areas (23) were determined to be hazardous because they collect flammable fluids over a period of time.

(12) Although designed to reduce potential ignition sources, the fuel tanks (without FSS) (24) are susceptible to fire/explosion from lightning, static discharge, and other ignition sources which cannot be completely eliminated.

(13) The cargo winch (61) is a hazard because an over-heated winch could ignite flammable fluids spilled in the compartment.

(14) The oxygen system (63) was determined to be hazardous because there is no provision for remote shutoff of oxygen supply in the event of oxygen line leakage or rupture.

CONCLUSIONS

1. The C-5 has potential fire hazard areas.
2. None of the hazards pose a threat sufficiently serious to require restriction of flight operations.
3. Two hazards require expedited corrective action. They are the wing fillet/lobe area (Hazard Worksheet No. 1) and the wing dry bay (No. 2). The FSS would not provide protection for the fire or explosion hazards in the wing fillet/lobe area nor for the explosion hazard in the dry bays.
4. Until FSS is installed, hazards in the remaining areas can be greatly reduced by implementing the applicable recommendations.
5. For those items where the fire potential is minimal, no corrective actions are required.
6. In all hazard areas where hydraulic fluid was the combustible material, a new hydraulic fluid with a higher flash/fire point would greatly reduce the probability of a fire hazard.
7. The Fire Suppression System, when installed, should provide early detection and adequate suppression of fires in locations covered by the FSS. The FSS may not detect a fire behind the cargo compartment insulation and panelling until the fire is exposed to the open cargo compartment.
8. With exception of fuel leaking onto the APU, no single-mode failures were found which could result in fire. All other hazards require at least two failures or malfunctions in order for a fire hazard to exist.
9. Most hazards found in this study concern items, components, or conditions common to aircraft. Similar hazards may be present on other aircraft.

RECOMMENDATIONS

Shown in parentheses is the agency which, in the opinion of the study group, should be OPR for initiating the actions recommended.

1. The following general recommendations are proposed:
 - a. All future modifications to the C-5 should be reviewed to insure that there are no new fire hazards designed or built in as a result of the modification. (San Antonio ALC/MAC/SPO)
 - b. Current programs to develop a hydraulic fluid with a higher flash/fire point should be continued. (AFSC)
 - c. Other aircraft should be examined for hazards of the nature identified in this study. (AFLC/AFSC)
2. The following specific recommendations are proposed as means of reducing or eliminating the primary fire/explosion hazards:
 - a. Wing Fillet/Lobe Area
 - 1) MAC should emphasize compliance with the T.O. 1C-5A-2-4 procedure requiring APU area scan prior to APU start. (MAC)
 - 2) Recommendations which may result from the present aerial refueling spillage study should be given top priority to correct the fire/explosion hazards resulting from fuel spillage. (San Antonio ALC)
 - 3) The APU fuel line in the wing fillet should be modified by replacing the Higgins fitting with a more reliable coupling and the lines should be rerouted with an expansion loop to reduce axial loads in the line. (San Antonio ALC)
 - b. Wing Dry Bays
The wires in the dry bays should be routed through conduits to prevent damage during maintenance actions. (San Antonio ALC)

3. The following corrective actions are proposed for the secondary hazards.

a. Flight Engineer's Panel

- 1) A method should be devised to allow inspection of the aerial refueling receptacle coupling outer shroud for failure of coupling inner seal. (San Antonio ALC)
- 2) Study the feasibility of installing a barrier or baffle to prevent hydraulic fluid and/or fuel from spraying onto the flight engineer's panel. Accomplish modifications recommended as a result of study. (San Antonio ALC/MAC)

b. AC/DC Elect Power and Distribution System

- 1) Establish optimum time change period for the aluminum wiring. Installation of copper wiring at this time is recommended. Review T.O. 1C-5A-6 inspection criteria for areas susceptible to hydraulic saturation to determine adequacy. (San Antonio ALC)

- 2) Establish an Analytical Condition Inspection (ACI) requirement to inspect the wiring feed-through grommets. (San Antonio ALC)

c. Exterior Lighting

- A study should be made to determine the maximum length of time allowed for operation of landing lights and restrictions incorporated in T.O. 1C-5A-1 to preclude overheating of landing lights/wiring. (San Antonio ALC/MAC)

d. Clamps Supporting Wiring and Hydraulic Lines

- 1) The original design clamp, which is subject to age deterioration, should be purged from the aircraft. This should be accomplished expeditiously on some basis other than the presently specified replacement only for worn/deteriorated condition (San Antonio ALC)

- 2) A better clamp should be identified/developed to support the hydraulic lines in the empennage. (San Antonio ALC)

e. Engines

A study should be made to determine the feasibility of improving the integrity of the vapor barrier and improving air circulation on the right hand side of the engine combustion section. If feasible, the necessary modifications should be accomplished. (San Antonio ALC/MAC)

f. Engine Driven Hydraulic Pumps

MAC should emphasize the importance of noting case drain flow failure printouts from MADARS. Correction of the cause for each such failure message can help preclude engine fire. (MAC)

g. Pylons

Installation of a new fire wall seal being developed under MIP SANBM 74-0096 should be expedited. (San Antonio ALC)

h. Flap Power Pack Assy

The control manifolds should be replaced as available rather than by attrition (San Antonio ALC)

i. 2/3 Power Transfer Unit (PTU)

Investigation of 2/3 PTU cartridge valve failures under MIP SANBM 74-0520 should be continued. (San Antonio ALC)

j. 1/2 and 3/4 Power Transfer Unit (PTU)

1) T.O. 1C-5A-1 should be revised to add the following:

If a PTU malfunction occurs during 1/2 or 3/4 PTU operation in flight, perform an inspection of the adjacent cargo compartment sidewall for indications of heat. (MAC)

2) T.O. 1C-5A-2-3 should be revised to add the following:

If a PTU malfunction occurs during ground operation, open access panel and inspect area for evidence of fire (prior to FSS). (San Antonio ALC)

k. Aircraft Batteries

Higher capacity nickel cadmium or lead acid batteries should be installed. (San Antonio ALC)

l. Chine Drain

1) The straight runs of plastic tubing between MLG wheels should be replaced with a more durable tubing. Lightweight aluminum tubing might be suitable. (San Antonio ALC)

2) Until replacement is accomplished, T.O. 1C-5A-6 should be revised to require regular inspection of these lines for leaks, breaks, or splits; or collection of fluid at low points. (San Antonio ALC)

3) Until replacement is accomplished, T.O. 1C-5A-1 should be revised to add the following:

In case of reservoir overflow during flight, monitor wheel well area for evidence of fire (prior to FSS). (IAC)

m. Emergency Generator

1) A warning system to indicate contactor failure should be installed. (San Antonio ALC)

2) A higher reliability contactor should be identified/developed and installed. (San Antonio ALC)

n. Crosswind Computer

1) A study should be conducted by ASD/EWJP to determine the temperatures to which the failed printed circuit cards have been exposed. (ASD)

2) If the ASD study indicates the failing cards are a serious heat source, the units should be shielded or otherwise isolated from fuel

sources, similar to the Radar Altimeter or Anti-Skid Control Box shielding.

(San Antonio ALC)

o. Troop Compartment Grill

The crew should be included in the loadmaster's briefing covering smoking restriction, in T.O. 1C-5A-1. MAC should enforce the existing requirement that crew and passengers not be allowed to smoke in the troop compartment unless they are seated in the troop area. (MAC)

p. MLG Extend/Retract System

1) MAC should continue inspection procedures established by MAC message DO/LG/IG 061715Z Jan 75 until fire detection is installed. (MAC)

2) Cause of failure for modified clutch assembly should be determined and appropriate action taken. (San Antonio ALC)

q. MLG Brakes and Tires

1) MAC should continue inspection procedures established by MAC message DO/LG/IG 061715Z Jan 75 until fire detection is installed (MAC)

2) Installation of fuses in any presently unprotected hydraulic lines in the landing gear system should be expedited. (San Antonio ALC)

r. Underfloor Fan

An operational procedure should be added to T.O. 1C-5A-1 to require emergency depressurization to shut down underfloor fans if flammable vapors are present or suspected. (MAC)

s. Wing Isolation Valves

A cover should be installed over the RH isolation valve. Efforts to provide the required cover under MIP SANBM 74-0223 should be continued. (San Antonio ALC)

t. Slat Proximity Control Box

T.O. 1C-5A-1 should be revised to require a periodic inflight inspection of aft troop compartment and wing rear beam area on all missions. (MAC)

u. Forward and Aft Underfloor Compartments

1) An inspection requirement should be added to T.O. 1C-5A-1 and 1C-5A-6 to require inspection of the underfloor area when hydraulic fluid and/or flammable cargo spills into cargo compartment. (MAC/San Antonio ALC)

2) T.O. 1C-5A-1 should be revised to require a 781 entry any time hydraulic fluid and/or flammable cargo spills into the cargo compartment. This entry would require inspection of the underfloor area prior to next flight. (MAC)

v. Fuel Tanks

FSS installation should be continued. (San Antonio ALC)

w. Cargo Winch

1) Until release of, and compliance with, TCTO 1C-5A-1740, which will provide drain holes in the winch compartment, MAC should emphasize the need for cleaning the compartment after any fluid spillage; and the need for thorough inspection prior to winch operation (MAC).

2) Instructions should be added in T.O. 1C-5A-9, requiring observation of winch during operation. (MAC)

x. LOX Converter

A study should be made to determine the feasibility of installing a remote oxygen shut-off capability mounted on the Flight Engineer's Console. Accomplish modifications recommended as a result of the study. (San Antonio ALC/MAC)

APPENDIX A
COMBUSTIBLES AND IGNITION SOURCES

COMBUSTIBLES

For the purpose of this review the following combustibles were considered as normally used or located in the C-5A aircraft.

- a. MIL-J-5624, JP-4 (Primary fuel)
- b. MIL-J-5624, JP-5
- c. MIL-H-5606, Hydraulic Oil
- d. MIL-L-7808, Lubricating Oil
- e. All nonmetallic materials such as fabrics, insulation, curtains, plastic panels, floor coverings, bunks, flight station lining, cargo compartment inner lining and tires.
- f. Combustible cargo

The various properties of the flammable fluids are summarized in Table I. Of the main combustible fluids aboard the aircraft only the jet fuels are capable of forming flammable vapor-air mixtures at the normal ambient temperatures outside the designated fire zones (Engine & APU compartments). As noted in Table I, these fuels have flash points of -10°F for JP-4 and 140°F for JP-5. This study is based on the fact that above -10°F JP-4 fuel will form a flammable vapor-air mixture. The jet fuels and the less volatile hydraulic oil (MIL-H-5606) and engine oil (MIL-L-7808) are capable of forming flammable vapor mixtures in the engine and APU compartments of the aircraft. These flammable vapor-air mixtures can be ignited by low intensity sparks or by a hot surface.

(Pages 158 & 19 Blank)

All nonmetallic materials used in occupied area of the C-5 are required to meet Federal Aviation Regulation requirements for self extinguishment after flame removal. These materials and their fire resistant characteristics are listed in Appendix B. Preventing the spread of fire in occupied areas is based on the use of materials that have a low rate of propagation such that a fire will not propagate beyond the immediate area of the ignition source.

Hot brakes and wheels have been a source of ignition in nearby hydraulic systems and/or the tires.

Combustible materials of all types are carried on or in the cargo compartment and may be palletized, boxed, bagged or packaged, or may be vehicles containing automotive fuels and lubricants.

IGNITION SOURCES

The following ignition sources were considered as being present in the C-5 aircraft.

- a. Surfaces which will ignite flammable fluids impinging thereon such as engines, APU, bleed air line and components, exhaust pipes, brakes, and electrical components.
- b. Electrical components subject to arcing.
- c. Electrical faults and arcing.
- d. Static electricity.
- e. Lightning
- f. Smoking paraphernalia - matches, cigarettes

One of the most widely used thermal ignition tests consists of dropping a small quantity of liquid into an open container treated to some specific temperature. The fluid, air and container are close to the same temperature. Ignition temperature is defined as the lowest temperature of the container at which a visible or audible evidence of a flame or explosion is observed. Tests of this type generally give the lowest ignition temperature reported. Minimum AIT values for the fluids investigated on the C-5A are shown in Table I. Duct surface ignition temperature data is based on tests using bleed lines and, even at zero air velocity, the surface temperatures required for ignition of the various fluids are considerably higher than their minimum autoignition temperature as determined in heated vessels under static air conditions. Requirements specify a maximum surface temperature of 500°F. The bleed air ducts are insulated with a maximum cold side temperature of 450°F with a 615°F duct wall temperature and an ambient temperature of 250°F. Tests conducted by the contractor show that with fluids impinging on the bleed duct inside the insulation, the minimum hot surface ignition point was 900°F. (A.H.B.)

Under ideal conditions, a minimum energy of about 0.2 millijoules (6×10^{-5} calories) is required for ignition of fuel in air. To put this in perspective, the energy of electrostatic discharge from a man can produce a static discharge of 15 millijoules. This is an exceedingly small amount of energy and most familiar ignition sources on the C-5A are considerably more energetic. These include electrical system arcing and static electricity. However, it should be noted that, in order

to have a fire ignited from electrical system arcing, the fuel/air mixture must be in its flammability range. A hydrocarbon will not burn while it is in the liquid phase and to generate sufficient vapor, the fluid must exceed the flash temperature as shown in Table I. If the electrical fault is a power short to ground, a fire may be ignited on a combustible soaked insulation; however, the amount of combustible is usually limited. Lightning strikes contain large amounts of energy, far in excess of the minimum required for ignition of flammable vapor-air mixtures. The fuel system is designed to minimize hazard due to lightning and, with the installation of the FSS fuel tanks inerting, additional protection will be provided. Areas outside the fuel tanks are not easily protected from lightning strikes.

Several sources of ignition exist in areas used or occupied by personnel. The sources may be the result of equipment failure or malfunction or of actions by personnel and may be overheat, sparks, open flames or embers. Incidents due to personnel may involve careless handling of smoking materials and the placement of objects adjacent to ignition sources. Oxygen is available in the crew station, courier, troop and cargo compartments. While oxygen is not a source of fire, it can cause a fire to occur spontaneously when it is released in the presence of many materials.

References: AFAPL TR-73-74
AFAPL TR-71-86
Aviation Fuel Safety (CBC Project No. CA-37-64)
Lockheed Report LG1U5283-1-1

TABLE I
COMPARISON OF FLAMMABILITY AND AUTOIGNITION PROPERTIES
OF COMBUSTIBLE FLUIDS

	<u>JP-5</u>	<u>JP-4</u>	<u>MIL-H-5606</u> <u>Hyd Fluid</u>	<u>MIL-L-780E</u> <u>Engine Oil</u>
Flash Point °F	140	-10	195	440
Fire Point	145 to 150	-5 to 0	225	460
Min Autoignition Temp °F	435	470	440	740
Duct Surface Ignition Point °F	900	920	960	1010
Flammability Limits in Air				
Lower Limits Vol %	0.6	1.3	.297	
Upper Limits Vol %	4.5	8.0	2.71	

Flash Point: The lowest temperature of the liquid at which it gives off vapor sufficient to form an ignitable mixture with the air near the surface of the liquid.

Fire Point: The lowest temperature of a liquid in an open container at which vapors are evolved fast enough to support continuous combustion.

APPENDIX B

NONMETALLIC MATERIALS

LOCKHEED-GEORGIA COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION
INTERDEPARTMENTAL COMMUNICATION

A N V O

TO D. O. Gunson

DEPT. 72-19 ZONE 454 DATE 3 June 1970

FROM C. B. Lovelace

DEPT. 72-19 ZONE 454 EXT. 7025

SUBJECT: C-5 INTERIOR MATERIALS

ITEM	MATERIAL	COMMENT
Cargo Compt Hardliner & Functional Cover	LS 34580-1 LS 34581-1 LS 34581-2 Rigid polyurethane foam sandwich between resin impregnated glass fabric	Meets the FAA requirements for fire resistant materials as outlined in Flight Standards Service Release 453
Cargo Compt Frame Covers, S/S 0001 thru 0044, MB-1, MB-2, Chain Stowage Boxes & Device Stowage S/S 0001 thru 0019	Glass fabric per STM 22-502 impregnated with epoxy resin per MIL-R-9300	(Same as above)
Cargo Compt Frame Covers Ships 0045 & up & MB-1, MB-2 Device Stowage S/S 0020 & up	KYDEX 100	No tests have been conducted. Vendor claims KYDEX is fire resistant in thicknesses over .04
Hyd. Service Centers	Compressed honeycomb core, aluminum per STM 28-003 Type I	Equal to or superior to normal honeycomb
Cargo Compt Trim Panel Edge Members	LS 34647-1 LS 34647-4 LS 34648-1 Vinyl - Semi-flexible	Slow burning to self-extinguishing
Cargo Compt and Troop Compt Insulation Batts	STM 26-703, Type II, Class I. 1.0" & 2.0" thick insulation - MIL-B-5924 Cover-STM 26-103 Class 4½ & Class 2½. STM 26-701 Type II, Grade AA, Class 2	Fire-resistant self-extinguishing. See Notes 1, 2, & 4 of Attachment

Addressee Re-tasks:

DATE

- FOR ACTION
- REPLY OVER YOUR DIGITAL
- PREPARE FIGHTER FOR ADDITIONAL SIGNALS
- COMMENT
- LET'S TALK IT OVER
- INVESTIGATE
- FOR INFORMATION
- PLEASE NOTE AND RETURN
- PLEASE FOLLOW UP

ON

REROUTING, SPECIAL INSTRUCTIONS AND FOLLOW UP DATE.

<u>ITEM</u>	<u>MATERIAL</u>	<u>COMMENT</u>
Cargo Compt Insulation Batts	STM 26-701, Type II, Grade AA 1.0" thick cover-STM 26-103, class 2 $\frac{1}{2}$. Fabricated per STP-51-208 Type 1, Class 3	Fire-resistant self-extinguishing. See Notes □ 1 & □ 2 of Attachment
Flt. Sta. & Crew Rest Area Insulation Batts	STM 26-701, Type III, Class 2, Grade AA. STM 26-103, Class 2 $\frac{1}{2}$ Orcon AN-4 Tedlar film	Fire-resistant self-extinguishing. See Notes □ 1, □ 2, & □ 3 of Attachment
Troop Compt Trim Panels & Modules	LS 34582-1 LS 34583-1, -2, -3 LS 34584-1 LS 34585-1 Rigid Polyurethane foam sandwich between resin impregnated glass fabric. An em- bossed flexible vinyl foam on all above LS's except LS 34582-1	Meets the FAA requirements for fire-resistant materials as out- lined in Flight Standards Service Release 453
Bled Air Ducts	Phenolic/Fiberglass	Self-extinguishing
Air Distribution Ducts	STM 26-103 STM 26-603	Fire-resistant self-extinguishing. See Note □ 1 of Attachment
Air Distribution Ducts (limited use)	STP 61-203, Type II, Class A, Grade 2 epoxy - fiberglass	350° heat resistant. Self-extinguishing
Underfloor Isolation Panels, Main Panel	STM 26-103	Flame-resistant. Self-extinguish- ing. See Note □ 1 of Attachment
Underfloor Isolation Panel Furnel Area	MIL-C-20595, Type I Class 3, Chloroprene coated nylon	Self-extinguishing. Has fire- retardent inhibitors
Rain Removal Fluid Lines, Duct Drain Lines, Potable Water Lines	Polyethylene	Will melt and burn
Air Conditioning Duct and Fan Mufflers	DAIP modified polyester resin & fiberglass	300°F heat-resistant flame re- tarders in resin, self-extinguisher
Upper Deck Floors	Aluminum Honeycomb	Heat resistant to 300°F will deform and delaminate at higher tempera- tures - will not support combustion

FLIGHT STATION MATERIALS

ITEM	MATERIAL	CHARACTERISTICS WHEN SUBJECTED TO FIRE OR INTENSE HEAT
Doors	<p>Three basic constructions are used for door assys:</p> <ol style="list-style-type: none"> 1. LS 34922 - .5 or .75 thick honeycomb panels core mat'1 is 5052 AL per STM 28-102. Face sheets are F/G per STM 22-506, with 3 MIL vinyl (Tedlar) painted surface one or both sides 2. LS 34653 - Panel - Core is polyurethane foam. Face sheets are fiberglass & vinyl (Panlam) 3. LS 34833 - Honeycomb panel core is alum., face sheets are thin gauge alum (.008 to .012) one or both sides are covered with vinyl sheets .020 thick (Panlam) 	<p>A. The laid-up F/G as well as "Comolite" F/G is self-extinguishing.</p> <p>B. The "Tedlar" decorative cov is rated as slow burning to self-extinguishing.</p> <p>C. The polyurethane foam is self-extinguishing.</p> <p>D. The "Panlam" decorative mat'1 is self-extinguishing.</p> <p>Panels and laminates will tend become unbonded at elevated temperatures (approx. 300°F & v</p>
Access Panel and Doors	LS 34863 Panel - Core is polyurethane foam. Face sheets are fiberglass & vinyl or F/G both sides (same basic construction as Item 2 above)	Same as above
Upper and Lower Side Consoles	LS 34939 & LS 34940 3/8" nylon paper (Nomex) core with F/G face sheets	Nomex is impregnated with phenolic resin and is self-extinguishing. It is also a low smoke generator
Glare Shield	Fiberglas Wool & nylon covering	Self-extinguishing Flame resistant - This material meets FAR 25.853 requirement. (Ltr. in file from vendor confirming this certification)
Reveal & Shrouds	ABSKYN (Thermo Formable Plastic) Laminate of A.B.S. & rigid polyvinyl chloride	Polyplastex Co. Letter dated Aug. 3, 1967 Material is self-extinguishing Flammability tests by U.S. Testing Co., Inc. 14072-1 dat Jan. 8, 1968
	Kydex (Thermo Formable Plastic)	Self extinguishing Test Method ASTM D-63556T Rhom & Haas Bul. PL-674B & ltr Sept. 10, 1969 C. H. Bryant (LIC) from J. B. Spencer (Rhom & Haas)
	Fiberglas	Self-extinguishing

ITEM	MATERIAL	CHARACTERISTICS WHICH SUBJECTS TO FIRE OR INFLAMES ITSELF
Panel Facing	Panlcam (Rigid polyvinyl chloride laminate)	Polyplastex Co. ltr. Aug. 3, 1967 Meets self-extinguishing and flame requirements of CC-T-111b Method 5905 & CC-T-191b Method 5902. Tests performed by U.S. Testing Co. Inc. Rpt. # 14072-1 dated Jan. 8, 1968
Bunk Mattress	Polyurethane Foam & Fabric Cover	Fire resistant per FIA Flight Standards Service Release 453
Pilot's & Crew Seats	Fabric Upholstery, Foam Cushions & Naugahyde Headrest & Armrest	Flame resistant per par. 4.3 of DODG0001 (documented in QTR)
Relief Crew Seats	Fabric Upholstery, Foam Cushions & Naugahyde Armrests	Flame resistant per DODG0001
Floor Covering Cabin & Troop Compartment	Vinyl with vinyl sponge underlay	Self extinguishing or non- burning (John Sneller ltr. dtd. Aug. 25, 1967 with attached report)
Blackout Curtain	Nylon vinyl coated	Self extinguishing or non- burning in accordance with Flt. Std. Service Release No. 453
Aisle Curtain	Wool Gabardine	Material is inherently flame proof since it is wool. Meets requirements of Flt. Safety Std. 453 per Clarke & Burchfield (vendor)
Lavatory Curtain	Vinyl coated fiberglass	Self extinguishing or non- burning per Flt. Safety Std. 453
Lavatory Floor Covering	Laminated rigid polyvinyl chloride	Self extinguishing
Student Instr Seats	Fabric upholstery, foam cushions & naugahyde on back & seat	Flame resistant per par. 4.3 of DODG0001 (documented in QTR)
Flt. Sta. & Pass- enger Overhead & Side Soft Trim	Vinyl facing on polyurethane foam - bonded to rigid fiberglass	Self extinguishing or non- burning per Flt. Safety Std 453. (John Sneller ltr. 6-19-67 & Aug. 25, 1967)
Crew Lavatory Water Tanks	Linear polyethylene	Flammable - classified as slow burning
Water System Tubing	Polyethylene MIL-P-3803	Flammable - classified as slow burning
Luggage Comat Restraint Nets	Nylon	Self extinguishing

ITEM	MATERIAL	CHARACTERISTICS WHEN SUBJECT'D TO FIRE OR EXTREME HEAT
Tables Flt Eng Navigator Conference	Formica Face Sheets Rigid Foam Core Wood Edging	Non-burning Self extinguishing Slow burning
Interior Paint	Cellulose Nitrate Lacquer	Will burn
Life Rafts	Neoprene Coated Nylon	Material to meet requirements of Flight Safety Regulation 453
Inflatable Escape Slides	Polyurethane coated nylon	Material to be flame resistant to meet requirements of Flight Safety Regulation 453

C.B. Lovelace
C. B. Lovelace

CEL:ba

cc: J. Clifford
R. D. Gilson
G. L. Rateneck

APPENDIX C

BLEED AIR DUCT IGNITION TESTS

APPENDIX C
BLEED AIR DUCT IGNITION TESTS

RECORD OF LOCKHEED LABORATORY TESTS

ATM FIRE INVESTIGATION

28 MAY 1970

This test was conducted as a result of the fire encountered on Ship 0011.

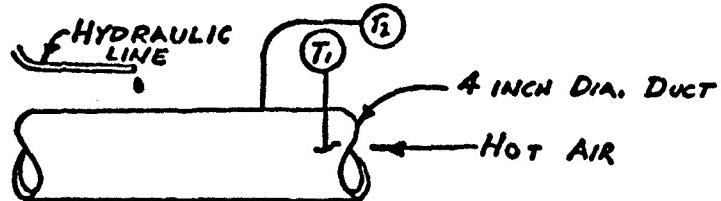
The environmental simulator was used for this test.

The R.H. ATM insulated surfaces were saturated with MIL-O-5606 hydraulic oil. This was accomplished by cutting the RTV surface on the insulation and pouring the oil on the felt insulation. The ATM was then operated with 550°F inlet air and with a 40 gpm hydraulic load. Surface temperatures on the machine scroll approached 900°F. However, after 36 minutes of operation, no fire resulted. A large volume of white smoke was present during this test.

A line was then located above the machine scroll thru which hydraulic fluid was allowed to drop on the scroll. The above test was repeated with a loose clamp (lower) on the ATM control valve. Again a large volume of white smoke but no fire.

Hydraulic fluid was then sprayed directly on the inlet valve and clamps. No fire.

The object of this test was to try to determine the Auto Ignition Point of MIL-O-5606 hydraulic oil. Test set up:



T₁ - Air Temp

T₂ - Pipe surface temperature

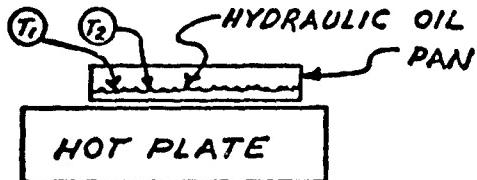
Fluid was allowed to drop from the hydraulic line onto the pipe surface. 16mm movies were made for each test.

TEST	T ₁ °F	T ₂ °F	REMARKS
1	465	410	White/gray smoke
2	544	490	" "
3	625	550	" "
4	695	610	" "
5	735	650	" "
6	810	710	" "
7	850	750	" "
8	910	800	" "
9			1 sq inch of saturated cloth on surface at 830°F. White gray smoke slightly darker due to smoldering cloth.

No ignition occurred during any of the above testing.

Testing continued on A409009.

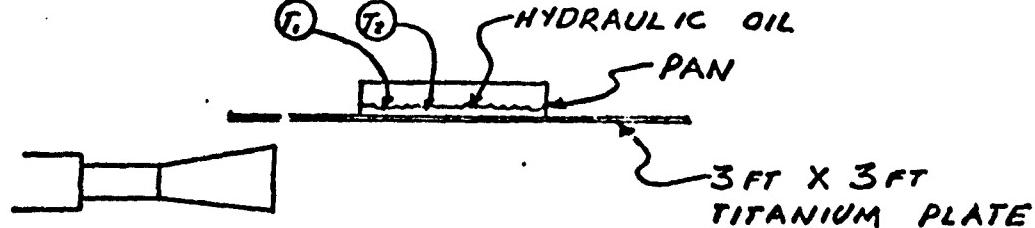
The next series of tests involved heating MIL-0-5606 oil in a pan.



T₁ & T₂ measured temperature of oil. Oil heated to approximate 470°F white/gray smoke. No fire.

Oil heated to 470°F white/gray smoke ignited by open flame (match). Black smoke after ignition.

Oil heated to 510°F. White/gray smoke. Ignition occurred; however, the source was not clearly noted. Black smoke after ignition.



APPENDIX D

**AIRCRAFT ELECTRICAL
WIRING HAZARDS REPORT ON GENERAL
PURPOSE AIRFRAME WIRE .**

**Aerospace Safety Engineering
Department
Lockheed-Georgia Company**

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REVISION PAGE		
REVISION NUMBER	REVISION DATE	REVISED PARAGRAPH NUMBER
A	17 November 1966	VI

CONTENTS

- I. INTRODUCTION AND REPORT SCOPE**
- II. BACKGROUND**
- III. BURNT WIRING AND WIRING FIRES**
- IV. FACTORS IN FAULTY WIRING**
- V. MASSIVE CURRENT OVERLOAD**
- VI. CONCLUSION**

I. INTRODUCTION

Electrical Systems

Practically all systems in a modern airplane depend upon electrical energy in some form or another, as a power producer (generator system), rotating devices (motors), control circuits (direct or by use of sys, solid state devices, etc.) and warning systems of all kinds. The means of transmitting this energy to all of the systems is through the utilization of wiring. The number one enemy in the electrical complex is the short circuit. This has been caused by original design, re-design, lack of consideration of the total environment, moisture, induction and human error. The most serious by-product of the short circuit is the electrical fire.

A study of electrical wiring fire hazards relative specifically to the C-5A involves the following general areas.

1. Choice of wire for various applications.
2. Specification of wiring process to be used.
3. Special attention to wiring items having high hazard possibility or other unique features.
4. Implementing of wiring in the individual systems.
5. Quality assurance to insure that requirements have been met.

Wire to be used in the C-5A has been chosen. Wiring process specification STP 65-101 has been prepared.

The last three general areas are being developed. Safety Engineering will monitor and coordinate with the design groups for maximum safety considerations particularly in potentially hazardous areas.

S C O P E

This report discusses general considerations in aircraft wiring fires and burnt wiring, then describes accomplishments and the approach being taken in C-5A design for wiring safety.

II. BACKGROUND

The major general purpose wire which has been used through the airframe industry is MIL-W-5086. This wire utilizes PVC (polyvinyl chloride) as a primary insulation and is jacketed with nylon; types II and III of this specification also include glass braids between the primary and jacket. Many problems have been associated with the use of MIL-W-5086; the major ones are:

- (a) Nylon cracking, which has been under investigation for the last 5 years.
- (b) Wet wire fires, an investigation of which resulted in Gelac discontinuing the use of Type II MIL-W-5086 shielded wire which was considered a fire hazard.
- (c) Corrosion. When PVC is operated at 175°F, corrosive fumes are emitted; this is below the rating of MIL-W-5086 which is 221°F (105°C).

Prevention of wiring fires and other wiring defects has been a key factor in the choice of wiring for the C-5A. A thorough study was made of the latest state of the art development in types of wires.

Based on studies and tests made by Lockheed's Material, Standards and Design groups, MIL-W-81044/2, Tin Coated Copper, Abrasion Resistant wire was chosen for general purpose use on the C-5A. MIL-W-81044 consists of a cross-linked polyalkene primary insulation and a cross-linked polyvinylidene fluoride

(Kynar) jacket which offers low and high temperature advantages over MIL-W-5086 as well as overload protection. In addition, MIL-W-81044 presents significant weight saving opportunities and has a number of hazard prevention features over the old MIL-W-5086 wire:

1. Substantially less smoking at currents in excess of 300% overload.
2. Crack resistance. The cross-linked structure of the polyalkene/polyvinylidene fluoride insulation makes it stress-crack resistant. Further, it is not moisture sensitive such as the nylon jacket on MIL-W-5086 wire.
3. Anti-melting characteristic. When overheated considerably beyond its temperature range, the insulation does not melt and drip off the conductor. It tends to decompose but stays in place on the wire. Therefore, at least partial insulation properties are retained and the possibility of fires from bare wires is reduced
4. No "wet wire" fires as have been experienced with MIL-W-5086.

H-Film (Kapton), Teflon and silicone rubber insulating systems were considered for the C-5A program. Such factors as function, cost, weight, physical properties and fabrication methods were the basis of the evaluation. H-Film would be lighter than MIL-W-81044 and offer higher temperature properties; however, there was no airframe usage or specification for this wire and the state-of-the art was such that it could not be recommended at the time of the selection. Teflon was not recommended as a general purpose wire because of cost and weight, however, it was specified for those applications where the properties of Teflon are required to meet design requirements.

Attention was focused on three aspects of wiring fires and other wiring defects:

- (1) Burnt wiring and wiring fires
- (2) Faulty Wiring
- (3) Massive Current Overload

These problems area are discussed below:

III. BURNT WIRING AND WIRING FIRES

Reports of aircraft electrical fires, including wiring fires, often do not differentiate between wiring or electrical components charring and/or burning in two and these same items supporting a flame. Even in aircraft general purpose wire, the objectives are to have the insulation at least "flame resistant". This means the insulation will not continue burning, beyond safe limits, after the source of heating has been removed.

The major hazard in defects of wiring leading to catastrophic fires, is that of an ignition source. Arcing or overheated electrical components and wiring create a high hazard probability in a combustible environment.

Many of the installation procedures of MIL-W-5088 and Lockheed specifications are directed toward the isolation of and protection from faulty wiring in combustible environments.

IV. FACTORS IN FAULTY WIRING

Heat and arcing associated with faulty wiring are isolated to the following:

1. Excessive currents in wire caused by faults in the wire or its circuit equipment.
2. Heat from the surrounding environment by conduction or convection. Exposure to flame is an extreme example of this.
3. Arcing from loose connections or faults, and the heating developed from the resistance of loose and faulted connections.

Mechanical factors are one of the broadest sources of wiring problems. A majority of troubles are caused by wires being scraped, cut, abraded, chafed, loosened at connections, shorted at connections, crushed, and pinched. Highest quality in initial installation and follow-on maintenance is essential. The relatively few wiring problems on the C-141 relate to mechanical factors. These problems involved wiring chafing against a (electrical connector) plug behind the flight engineer's panel, wiring chafing in wing and improperly clamped wire chafing in the engine nacelle. Suitable corrective and quality control actions have been taken on these defects.

Like everything else, wiring ages. On types used in the past, cracking of insulation was the major effect of aging. Environmental factors of heat, humidity, and vibration, are contributing factors to the deterioration of insulation. Wiring deterioration has contributed to hazards in some of our earlier century series fighters.

Wiring specifications spell out resistance of insulation to aircraft fluid and in special cases, for acids. Installation practices have an objective to preclude the possibility of hydraulic fluids, fuel, and other fluid leaks dripping on wiring or immersing wiring.

Layout and routing of wires is an early phase in design to prevent mechanical damage to wires and protection against hazardous faults. Protection against electromagnetic interferences is a companion prize consideration in early phases of design. In modifications and major maintenance, adherence to good wiring practices is equally important.

Investigating the wreckage of a catastrophic fire of a jet utility trainer a few years ago revealed that the main power leads were routed with distribution feeders. Also, power wiring was found to have insufficient clearance to oxygen lines. Both of these defects are direct violations of MIL-W-5088.

An extreme installation wiring hazard in a business jet transport was caused by a new cable clamp which could be installed in a manner where the clamp tightening screws scraped the insulation from the wires causing faults and burning. Needless to say, these clamps were replaced by safe items.

FAA Safety messages and articles in Safety magazines consistently show mechanical problems as the major cause of wiring defects. Besides mechanical damage to wiring incurred during normal aircraft operation and installation, a considerable amount of wiring damage is caused by careless and improper maintenance. Damage also results from carelessness of maintenance personnel working on equipment near wiring. In a modern, high performance aircraft, electricity is used for so many functions, that wiring is as widespread and complex throughout the aircraft, as network of nerves are throughout the human body. This tendency is increasing. Not only wiring for normal

electric services, actuators, switching devices, and instrumentation; but in the C-5A, additional control, monitoring and computing requirements cause a large increase in wiring requirements. The MADARS itself requires a private network of wires throughout the aircraft. Maintenance done in virtually any area of the C-5A will have wiring as a consideration.

Design specifications for the wire used normally takes care of environmental effects on wire. The main consideration here is heat resistance. Taken into account are possible bleed air leaks, high temperature areas of the airplane, and long term exposure to humidity. Wire specifications also provide for special wire which must operate during and after a fire. Installation practices of protective tubing and use of special tape protects against wiring damage in wheel wells, from shifting cargos and other special hazards. Since wiring problems are recognized as such a common hazard, designers are more reluctant to compromise weight, space and cost for lower safety factor wiring and installation practices.

V. MASSIVE CURRENT OVERLOADS

Data was collected to learn more about the behavior of various wire constructions under conditions of extreme current overload. Such conditions may occur when there is some form of catastrophic failure of a protective device. In the tests described below, five wire constructions either commonly used or proposed for general use in aircraft were subjected to identical tests.

All specimens were Awg. 22, 19 strands.

5086 I MIL-7-5086, type I. A polyvinylchloride/nylon insulation system.

Wall thickness .020 inch.

5086 II MIL-W-5086A, Type II. A three part insulation system consisting of polyvinylchloride primary insulation covered with fiber glass braid, jacketed with extruded nylon. Wall thickness .022 inch.

TFE MIL-W-16878, Type E. A polytetrafluoroethylene insulation system. Wall thickness .009 inch.

H-Film H-Film/FEF construction utilize two separate tapes each overlapped 50% with a .0005 inch fluorocarbon dispersion over the outside layer. Insulation wall thickness .013 inch.

81044 MIL-W-81044/2. A radiation cross linked polyalkene/polyvinylidene fluoride system. Insulation wall thickness .019 inch.

TEST METHODS.

Single Wire

Single conductor specimens, approximately 22 inches in length, were held in a horizontal position between two bench vises, as shown in the following photographs. The primary voltage of a 60 cps step down transformer was rapidly increased with a manually operated autotransformer to reach the desired test current in less than two seconds. This current was measured with an ammeter in series with the specimen. The test was terminated at the end of five minutes in those cases where the conductor did not fuse.

At each test current the time at which each of the following events occurred was recorded: (a) smoke (b) flame ignition (c) fusing of conductor and (d) flame extinction.

Subsequent to the completion of each test, each specimen was visually examined and the observations were recorded.

Cable Bundle

Seven-wire cable bundles were tested by applying the voltage to the center conductor using the same test apparatus described above.

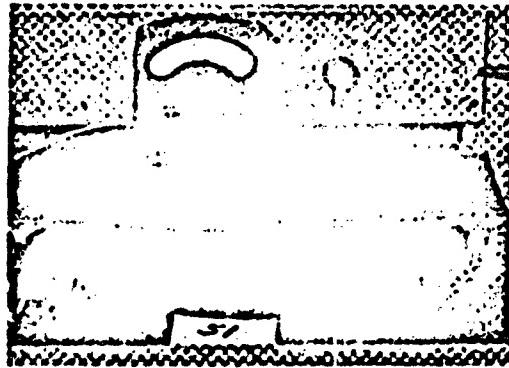
OBSERVATIONS AND FACTUAL DATA

Single Wire

20 Amperes

A test current of 20 amperes for five minutes did not damage TFE, H-Film or 810bh wire, but did cause a minor amount of melting and flowing of the 5086 Type I and Type II insulation.

20 Amperes
(all elapsed times in seconds)



Reproduced from
best available copy.

5086 I

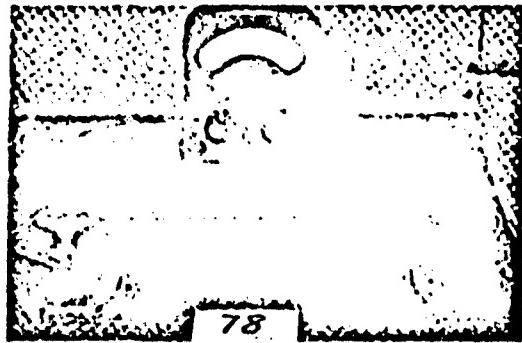
Smoke none

Flame Ignition none

Fusing none

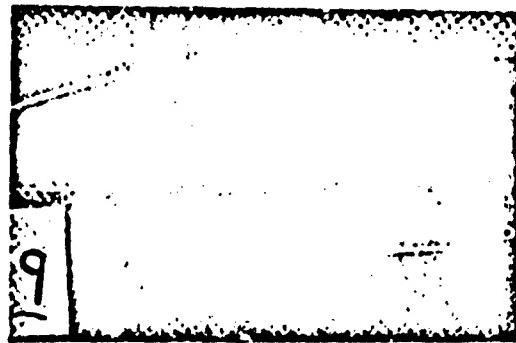
Insulation melted and flowed

20 Amperes
(all elapsed times in seconds)



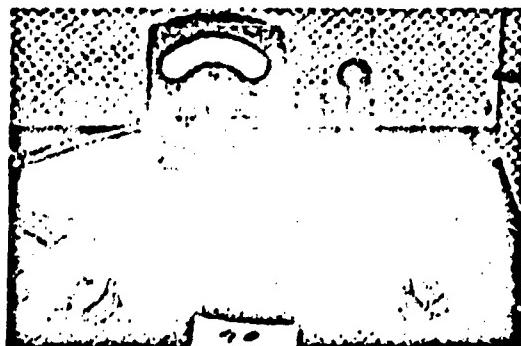
5086 II

Smoke none
Flame Ignition none
Fusing none
Insulation melted and flowed
through ruptured jacket.



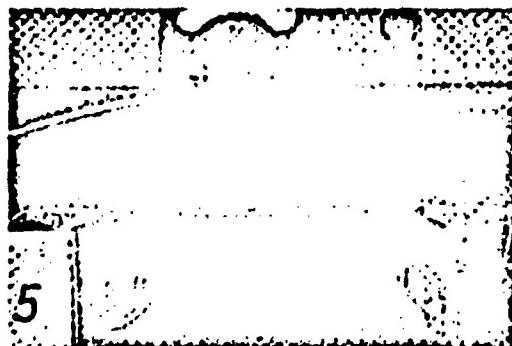
TFE

Smoke none
Flame Ignition none
Fusing none



H-Film

Smoke none
Flame Ignition none
Fusing none



81044

Smoke none
Flame Ignition none
Fusing none

30 Amperes

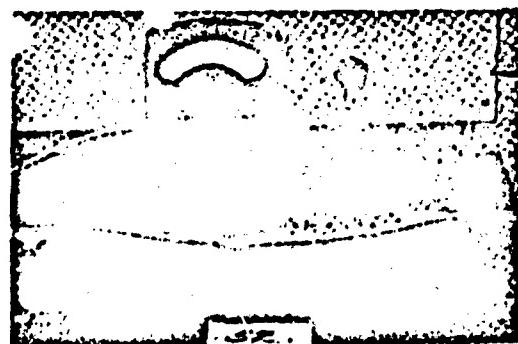
At 30 amperes all of the wires exhibited some damage. The mechanism of degradation is quite different for each insulation system.

Both 5086 constructions are susceptible to melting and rapid disintegration.

- Only brittle fiber glass braid is left on the 5086 Type II wire. The TFE insulation, on the other hand, does not melt, but does split and fall, thus leaving large areas of conductor exposed. The first stage of damage to the H-Film construction is the melting of the FEP that serves to bond the various layers of H-Film tape together. The FEP flows out through the fluorcarbon dispersion coating forming small globules. The 81044 wire is damaged by charring of the insulation system.

No flaming was observed with any of the wire types, and only the 5086 Type I wire fused.

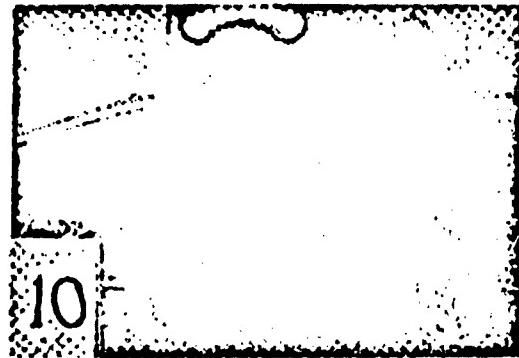
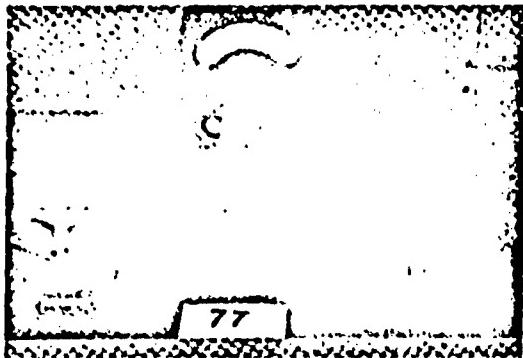
30 Amperes
(all elapsed times in seconds)



5086 I

Smoke	23
Flame Ignition	none
Fusing	74
Insulation melted and flowed off conductor	

30 Amperes
(all elapsed times in seconds)

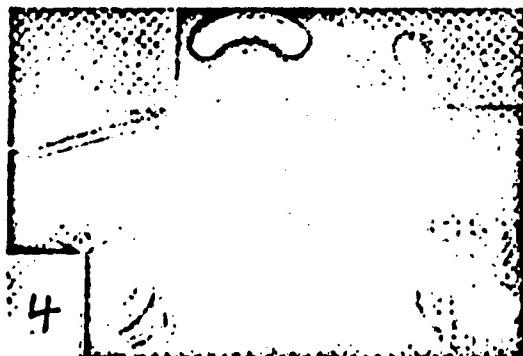
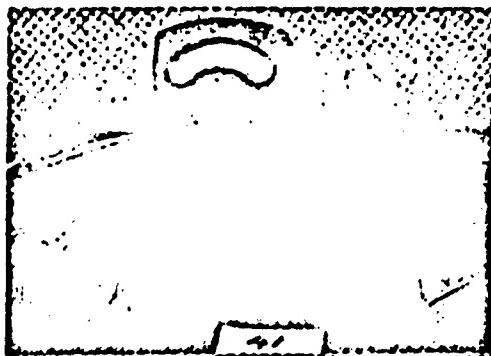


5086 II

Smoke 15
Flame Ignition none
Fusing none
Insulation decomposed into smoke
leaving only brittle fiber glass braid

TFE

Smoke 58
Flame Ignition none
Fusing none
Insulation split baring conductor



H-Film

Smoke 165
Flame Ignition none
Fusing none
FEP melted

8104

Smoke 82
Flame Ignition none
Fusing none
Some charring

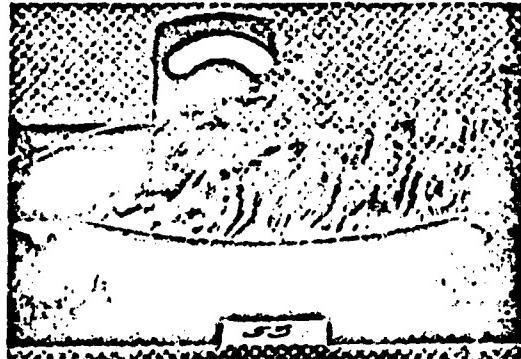
40 Amperes

The first fires were observed at 40 amperes. They were observed in the TFE and H-Film constructions and were not severe in either case.

The other forms of damage previously described at lower currents were observed for each wire type, and in each case the damage occurred earlier and was more extensive.

40 Amperes
(all elapsed times in seconds)

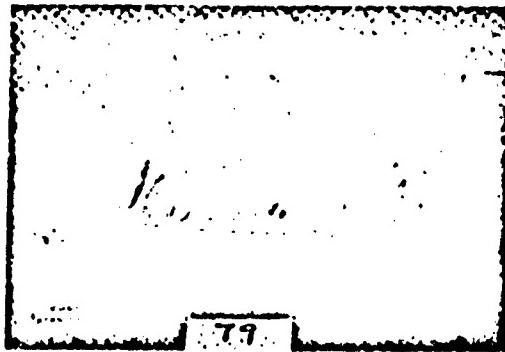
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5086 I

Smoke	10
Flame Ignition	none
Fusing	21
Insulation decomposed into smoke and dripping particles	

40 Amperes
(all elapsed times in seconds)

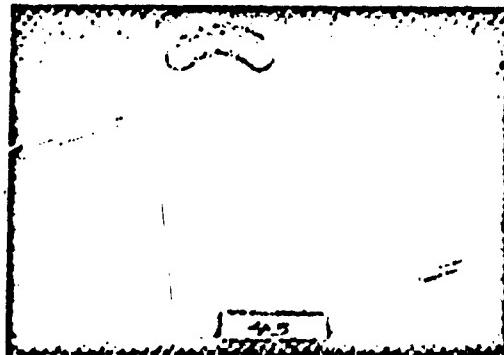


5086 II

Smoke	8
Flame Ignition	none
Fusing	58
Insulation decomposed into smoke and dripping particles	

TF&

Smoke	20
Flame Ignition	24
Fusing	26
Flame Extinction	27
Insulation split baring condctor	



H-Film

Smoke	5
Flame Ignition	35
Fusing	36
Flame Extinction	36
FEP melted and charred	

81044

Smoke	32
Flame Ignition	none
Fusing	55
Charring	

50 Amperes

All of the effects observed at 40 amperes occurred even more rapidly at 50 amperes.

The insulation of both 5086 constructions was totally consumed within a few seconds while the other three wires retained their insulations for varying lengths of time.

50 Amperes
(all elapsed times in seconds)



5086 I

Smoke

3

Flame Ignition none

Fusing 11

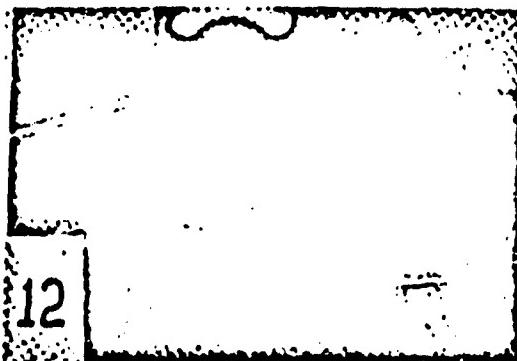
Insulation decomposed into smoke and
dripping particles

50 Amperes
(all elapsed times in seconds)



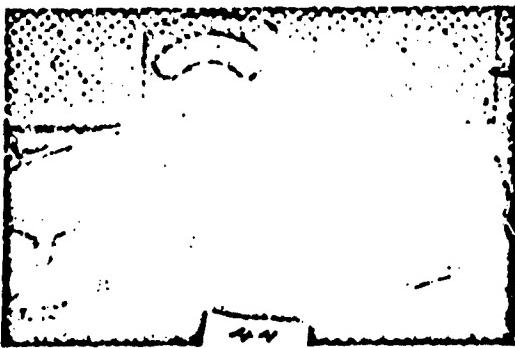
5086 II

Smoke 1
Flame Ignition none
Fusing 19
Insulation decomposed into smoke and dripping particles



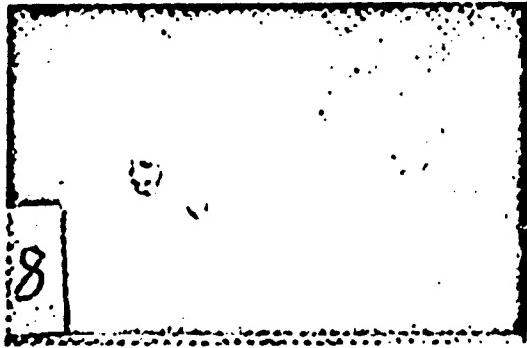
TTF

Smoke 4
Flame Ignition 10
Fusing 12
Flame Extinction 12
Insulation split baring conductor



H-Film

Smoke 2
Flame Ignition 15
Fusing 16
Flame Extinction 16
FEP melted and charred



81044

Smoke 12
Flame Ignition 24
Fusing 28
Flame Extinction 29
Some charred remains on conductor

60 Amperes

The effects noted at 50 amperes generally appeared more rapidly with the TFE insulation splitting in the first few seconds. The fires in the TFE and H-film specimens appeared to be more vigorous than those which occurred at 50 amperes.

60 Amperes
(all elapsed times in seconds)

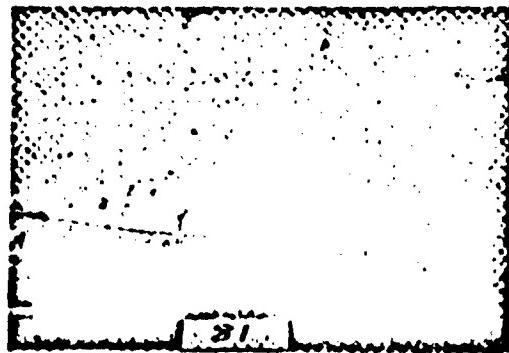


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5086 I

Smoke	3
Flame Ignition	none
Fusing	7
Insulation decomposed into smoke and dripping particles	

60 Amperes
(all elapsed times in seconds)



5086 II

Smoke 1
Flame Ignition none
Fusing 7
Insulation decomposed into smoke and
dripping particles



TFE

Smoke 1
Flame Ignition 6
Fusing 7
Flame Extinction 8
Insulation split baring conductor



H-Film

Smoke 1
Flame Ignition 8
Fusing 9
Flame Extinction 9
FEP melted and entire insulation
system charred

81084

Smoke 5
Flame Ignition none
Fusing 15
Some charred remain on conductor

70 Amperes

All the wires fused in 3 to 7 seconds. Both the H-Film and 81044 flames burned for a few seconds after the conductor fused, with the 81044 burning longer. The fire in the TFE wire extinguished itself in less than one second after fusing.

70 Amperes
(all elapsed times in seconds)

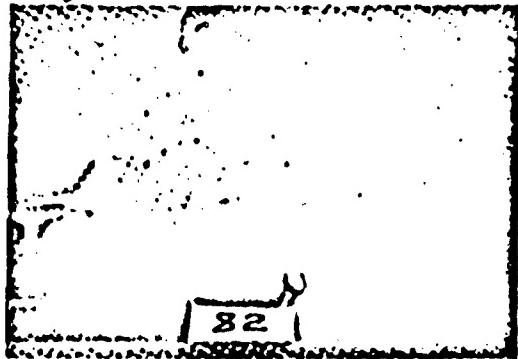


5086 I

Smoke	1
Flame Ignition	none
Fusing	3
Insulation decomposed into smoke and dripping particles	

70 Amperes
(all elapsed time in seconds)

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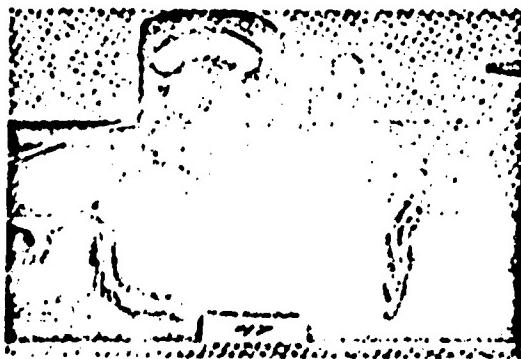
5086 II

Smoke	1
Flame Ignition	none
Fusing	4
Insulation decomposed into smoke and dripping particles	



TFE

Smoke	1
Flame Ignition	4
Fusing	4
Flame Extinction	4
Insulation split baring conductor	



H-Film

Smoke	1
Flame Ignition	5
Fusing	5
Flame Extinction	7
PEP melted and entire insulation system charred	

81044

Smoke	4
Flame Ignition	7
Fusing	7
Flame Extinction	13
Some charred remains on conductor	

OBSERVATIONS AND FACTUAL DATA

7 Conductor Bundles

30 Amperes

The only damage caused by the 30 ampere test occurred with 5086 constructions. The insulation of the Type I wire melted and charred, leaving parts of all conductors bare. The Type II construction also showed some melting and charring.

40 Amperes

All of the wire constructions were damaged at 40 amperes.

The 5086 I damage was of the same form as that observed at 30 amperes, but it occurred more rapidly. With 5086 II the insulation on the center wire was completely consumed, leaving only brittle fiber glass braid on the conductor. Heating caused the twisted bundle to become quite loose. This unwinding effect was not observed with the other four wire types.

The TFE insulation exhibited extensive splitting leaving parts of all conductors in the bundle exposed, with two or more uninsulated wires in contact. The first instance of burning occurred at 40 amperes in a TFE wire bundle. This could have been an anomalous result which can only be explained after further investigation.

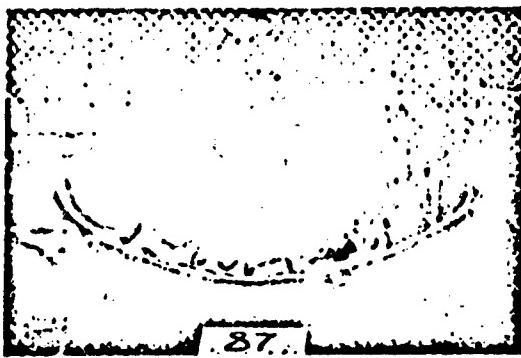
Blocking was observed in all wire types except 5086 I, where the insulation was virtually completely consumed. The most severe blocking occurred with the H-Film constructions, where the FEP bonding melted and flowed causing all of the wires in the bundle to stick together.

50 Amperes

At 50 amperes fusing occurred much more rapidly; 23 seconds (5086 II) to 47 seconds (81044). As a result, the bundles were exposed to elevated temperatures for a shorter period of time. The ensuing damage was generally less than that which occurred at 40 amperes.

The second instance of burning occurred at 50 amperes with 5086 II. The following photograph shows the fire, which lasted for 24 seconds after the current-carrying conductor fused.

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87

5086 II
7-Conductor Bundle
50 amperes
Smoke 7 seconds
Flame Ignition 20 seconds
Fusing 23 seconds
Flame Extinction 47 seconds

60 Amperes

The tests were terminated rapidly at 60 amperes. Thus the effects were not as severe as those observed at either 40 or 50 amperes. The most severe effect was the baring of conductors - in the cases of the 5086 I wire where the insulation flows and chars, and TFE where the insulation splits.

VI. CONCLUSION

The observations and factual data on the massive overload tests indicate that most types of wire will burn. No ideal wire exists for general purpose air frame application. However, the massive overload tests indicate that 5086 wire degrades before all the other types of wire tested, and that MIL-W-81044 wire flame ignition and fusing occur later than the TFE or H-film wire. The longer time interval allows greater opportunity for the circuit protection to operate and protect the wire prior to wire fire or wire fusing. Aerospace Safety Engineering will continue to study this problem in hopes of finding an even safer wire. Although it is somewhat early to make a judgement, the next step forward toward safety in the wire field may be an entirely new concept. Development in this field will be closely monitored.

ACKNOWLEDGEMENT

The massive overload tests on the preceding pages were performed by the Raychem Corporation at the request of Aerospace Safety Engineering, Department 72-11, Lockheed Aircraft Corporation.

APPENDIX E

OPERATIONAL FIRE HAZARD WORKSHEETS

OPERATIONAL FIRE HAZARDS WORKSHEET

WJC: N/A DATE: 30 Jan 1975 HAZARD NO: 1
NOMENCLATURE: Wing Fillet/Lobe

LOCATION: Lobe Panels and under Wing

IGNITION: TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION

FLAMMABLE MATERIAL: JP-4 and hydraulic fluid

STATEMENT OF HAZARD: 1. JP-4 leaking into wing fillet during serial refueling (AR) or from a loose Wiggins fitting on the APU fuel line and ignited by an electrical malfunction. 2. JP-4 leak in the area from fuel spilled during AR or a loose Wiggins fitting on the APU fuel line and running down the fuselage into the APU inlet or exhaust.

DISCUSSION:

The APU fuel line in the fillet area contains a hard-seal Wiggins fitting (not the flexible wiggins fittings) which has a history of leakage due to axial movement of the fuel line. Fuel can leak into the wing fillet/lobe areas either from this fitting or from aerial refueling. 1. During flight the fillet/lobe area appears to be well ventilated and probability of a fire/explosion is low and damage would probably be limited to the fillet/lobe panels. Sources of ignition in this area are confined to the leading edge lobe fairing forward of the wing SPARS. The sources are pressure vessel electrical wiring feed through, hot airducts, AR isolation valve, and the cooling air fan. The most probable source of ignition in this area would be a short in the electrical wiring. The hot airducts have temp. sensors, the AR isolation valve is hermetically sealed and the cooling air fan is turbine powered and isolated in a plenum chamber. Fuel accumulation in this area is unlikely due to the loose mating of the fillet panel to the fuselage and drain holes allowing drainage down the side of the fuselage. 2. During ground operation fuel from AR or leaking APU fuel line in the fillet/lobe area running down the fuselage into the APU intake/exhaust presents the greatest probability of fire/explosion. The malfunction of the APU fuel line presents the greatest hazard in that it can support a fire/explosion, whereas fuel from AR spillage would be of limited quantity.

CONCLUSION:

Fuel leaking from the APU line is a fire hazard; moreso than fuel accumulation due to AR spillage.

PANEL RECOMMENDATION: (Use back if necessary)

- 1) MAC should emphasize compliance with the T.O. 1C-5A-2-4 procedure requiring APU area scan prior to APU start. 2) Recommendations which may result from the present aerial refueling spillage study should be given top priority to correct the fire/explosion hazards resulting from fuel spillage. 3) The APU fuel line in the wing fillet should be modified by replacing the Wiggins fitting with a more reliable coupling and the lines should be rerouted with an expansion loop to reduce axial loads in the line.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: N/A DATE: 30 Jan 1975 HAZARD NO: 2
NOMANCLATURE: Wing Dry Bays

LOCATION: In Wing box between inboard and outboard engines
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: JP-4/Hydraulic oil
STATEMENT OF HAZARD:

Electrical wiring in this area could arc from breakage or damaged insulation, igniting leaking fuel.

DISCUSSION:

Fuel lines in this compartment include three shut-off valves and associated wiggins couplings. Fuel leakage is possible. Ventilation is provided in flight to produce a change of air each two minutes. Staticly and during taxi, the vent air flow through the compartment is low to nil. Although all electrical circuits are protected by circuit breakers, an explosion/fire could occur if there is a flammable mixture present at the time the arc occurs. The FSS provides detection and extinguishing capability in this compartment but would not prevent an explosion. Making the compartment inert with LN₂ would resolve the problem but would require sealing the compartment and adding climb and dive valves in each compartment. Another solution would be to run the electrical wiring inside conduits to prevent damage which could result in ignition of an explosive mixture. Since the valves located in this cavity have explosion proof motors, they are not considered to present any additional hazards.

CONCLUSION:

It is possible for a hazardous condition to exist in this compartment.

PANEL RECOMMENDATION: (Use back if necessary) 1. The wires be routed through conduits to prevent damage during maintenance. 2. Insure that an inspection of the wires is made after maintenance action in the compartment prior to closure of access panel.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

KJC: 12 AAU DATE: 30 Jan 1975 HAZARD NO: 3
NOMENCLATURE:

LOCATION: Flight Engineers (FE) instrument panel.

IGNITION TEMPERATURE DUE TO NORMAL OPERATION — MALFUNCTION

FLAMMABLE MATERIAL: JD-4 and hydraulic fluid

STATEMENT OF HAZARD:

Flammable fluid leaking from AR receptacle coupling onto the Flt Engineers panel.

DISCUSSION:

The refueling receptacle coupling has an inner and outer seal both of which must fail to allow leakage.

The coupling can and has leaked during or just after aerial refueling. In all cases it has been detected by the flight crew before the fluid has contacted an ignition source. The electrical components probably would not ignite a fire unless a malfunction of a component occurs at the same time as the leakage occurs.

Leaking fuel would probably leak into the cockpit area prior to getting behind the FE's panel. This is due to the location of the line low point being below the access opening into the FE panel; however, a spray could get behind the panel prior to being detected. The fuel coupling is shrouded which would reduce the possibility of fuel spray; however, there is no means of detecting a leak of the inner, primary seal. The temperature of the malfunctioned electrical component would be detected prior to reaching a temp. high enough to ignite hydraulic fluid or JP-4 in a liquid form.

CONCLUSION:

JP-4 can and has leaked into the cockpit from the AR receptacle coupling and is a hazard.

PANEL RECOMMENDATION: (Use back if necessary)

- 1) A method should be devised to allow inspection of the aerial refueling receptacle coupling outer shroud for failure of coupling inner seal.
- 2) Study the feasibility of installing a barrier or baffle to prevent hydraulic fluid and/or fuel from spraying onto the flight engineer's panel. Accomplish modifications recommended as a result of study.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: Numerous DATE: 30 Jan 1975 HAZARD NO: 4
NOMENCLATURE: AC/DC Electrical Power and Distribution Sys

LOCATION: From Engine and APU generators & external Power Receptacle to Circuit Breaker Panels.
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: Hydraulic Fluid/Oxygen/Oil/JP-4
STATEMENT OF HAZARD:

Possibility of malfunctioning electrical wiring igniting a combustible.

DISCUSSION:

Review of the following item installation was accomplished: a. Engine generators and feeder system, b. APU generators and feeder system, c. AC/DC electrical feeder system, d. AC load distribution panel, e. Generator and bus tie contractors, f. External power plug, g. External power contactor, h. Transformer rectifiers.

Problems were noted in the following areas: a. Aluminum wire is used from the pylon disconnect to the AC load center in the generator system. This has been a problem on previous aircraft because vibration/aging causes this type wire to become stiff, brittle and subject to breakage, b. Generator wiring in the engine, pylon and APU is subject to frequent saturation with hydraulic fluid, c. AC feeder wires under the catwalk on the right side of the aircraft are subject to frequent hydraulic saturation where they pass the two hydraulic service centers, d. Initially installed wire bundle clamps have deteriorating insulator. This item is covered separately (See Hazard Worksheet No. 6). e. Damaged or missing wiring feed-through grommets behind the navigator's panel have caused deterioration of insulation, arcing, and fire. This area has been thoroughly inspected and the situation corrected. However, there are numerous other areas in the aircraft where such grommets are used. These areas have not been subjected to thorough inspections.

CONCLUSION:

Further action is required on the problem items.

PANEL RECOMMENDATION: (Use back if necessary) 1. Establish optimum time change period for the aluminum wiring. Installation of copper wiring at this time is recommended. Review inspection criteria of areas susceptible to hydraulic saturation to determine adequacy. 2. Establish an Analytical Condition Inspection (ACI) requirement to inspect the wiring feed-through grommets.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 44 --- DATE: 30 Jan 1975 HAZARD NO: 5
NOMENCLATURE: Exterior Lighting

LOCATION: Wing tip, NLG, MLG, Fuselage, Empenage
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: Hydraulic/JP-4
STATEMENT OF HAZARD:

Possibility of external lighting system causing fire.

DISCUSSION: The navigation, wing leading edge, and upper anti-collision lights were reviewed and little chance of any malfunction occurring when a combustible is available. The lower anti-collision light is subjected to hydraulic fluid but the operating and malfunction temperatures are reported below the danger point. The taxi lights wiring could possibly arc to the airframe if a taxi light is lost in flight. Probability of ignition of hydraulic fluid is low due to the airflow through the areas during flight and taxi. The landing lights would be subjected to JP-4 during taxi if leaks occur outboard of pylons one and four. Probability of lamp induced combustion is considered low due to airflow. Fuel could get to wire from power transformer to the lamp. This wire could and has overheated if lamp is used for an extended period, or if a 1000 watt lamp is installed in lieu of the 600 watt lamp. Lockheed reports 900° F temperature at lamp contacts with 1000 watt lamp installed. This will radiate back through wire. Additional temperature data is shown on page 69.

CONCLUSION:

A hazard exists if the temperature of the landing light wire from the lamp to the transformer exceeds the JP-4 ignition temperature.

PANEL RECOMMENDATION: (Use back if necessary)

A study should be made to determine the max. length of time allowed for operation of landing lights and restrictions incorporated in the Dash 1 to preclude overheating of landing lights/wiring.

REPLY/STATUS: (Use back if necessary)

LANDING LIGHT TEMPERATURES

ALL TEMPERATURES WERE TAKEN WITH THE LIGHT RETRACTED

	BULB	10 MIN.	20 MIN.	30 MIN.	60 MIN.	120 MIN.	STABILIZED
1.	1000 Watt 600 Watt	300°F 165°F	380°F 220°F	455°F 255°F	520°F 320°F	560°F 375°F	610°F 415°F
2.	1000 Watt 600 Watt	150°F N/A	170°F -	203°F -	265°F -	308°F -	365°F 250°F
3.	1000 Watt 600 Watt	137°F N/A	175°F -	205°F -	255°F -	290°F -	360°F 224°F

1. Temperature pick-up on wire immediately outside of insulator.
2. Temperature pick-up adjacent to clamp about 4 inches up from #1.
3. Temperature pick-up between canopies which separate door actuator and bulb.

Wire is made in two parts. The first part, about 2½ to 3 inches adjacent to the bulb, is nickel plated. It then splices to tinned copper wire. The jacket is silicone impregnated fiberglass and is good for 392°F (200°C).

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: DATE: 30 Jan 1975 HAZARD NO: 6
NOMENCLATURE: Clamps supporting wiring and hydraulic lines

LOCATION: Throughout the aircraft

IGNITION TEMPERATURE DUE TO NORMAL OPERATION

MALFUNCTION X

FLAMMABLE MATERIAL: Hydraulic fluid/oxygen/JP-4

STATEMENT OF HAZARD:

Deterioration of insulators on initially installed clamps causing chafing of electrical wires, and hydraulic lines.

DISCUSSION:

1. The insulators on the majority of the originally installed clamps are age deteriorating with the consequent hazard of worn wires arcing and hydraulic leaks. It has previously been determined that the clamps will be replaced with standard MS type ones on a conditional basis during base and depot maintenance. Many of the clamps are extremely inaccessible and some are accessible only during PDM. This inaccessibility hampers proper conditional inspection increasing the probability of chafing causing electrical shorting and hydraulic leakage. Replacement of all the originally installed clamps regardless of condition would be required to eliminate the hazard.
2. In addition, the clamps supporting the hydraulic lines in the vertical stabilizer are breaking. This has been attributed to vibration and flexing of the tail.

CONCLUSION:

Further action is required to assure replacement of the original design clamps and to provide a clamp capable of surviving the vibration and flexing in the empennage.

PANEL RECOMMENDATION: (Use back if necessary) 1. The C-5 should be purged of all clamps of the deficient design. This should be accomplished expeditiously on some basis other than the presently specified replacement only for worn/deteriorated condition. 2. A better clamp should be identified/developed to support the hydraulic lines in the empennage.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 23 DATE: 30 Jan 1975 HAZARD NO: 7
NOMANCLATURE: Engines

LOCATION:

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: Engine oil, Hydraulic oil, JP-4 deicing fluid and elect. wiring.
STATEMENT OF HAZARD:

Ignition of flammable material by hot surface, failed rotating equipment, shorted electrical wiring, hot gas leakage or malfunctioning electrical components.

DISCUSSION:

All engines are susceptible to fire due to hot operating conditions, accessory failures, and the presence of flammable material. The C-5 engines have fire detector loops in the accessory section and apron and a two shot halon 1202 (DB) fire fighting capability. The main problems have been in vapor barrier leakage combined with hydraulic pump failure, or fuel leakage. One incident is believed to have been caused by deicer fluid. All necessary actions to correct these problems are believed to have been taken.

Explosions originating aft of the vapor barrier could have possibly been prevented if there had been better circulation of air on the R.H. side of the combustion section of the engine. Recoup air outlets presently provide circulation on the top, bottom and L.H. side of the engine.

CONCLUSION:

Problems with the vapor barrier and poor air circulation on the R.H. side of the engine contribute to the fire hazard potential on the engine.

PANEL RECOMMENDATION: (Use back if necessary)

A study should be made to determine the feasibility of improving the integrity of the vapor barrier and improving air circulation on the right hand side of the engine combustion section. If feasible, the necessary modifications should be accomplished.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

45AEA/
WUC: CEA/EEA/CEA DATE: 30 Jan 1975 HAZARD NO: 8
NOMENCLATURE: Engine driven hydraulic pumps

LOCATION: Engines
IGNITION TEMPERATURE DUE TO NORMAL OPERATION
FLAMMABLE MATERIAL: Hydraulic fluid
STATEMENT OF HAZARD:

A ruptured hydraulic pump provides hydraulic fluid into the engine cowling, which could be ignited.

DISCUSSION:

Recent failures of some hydraulic pumps have resulted in broken cases. This allows hydraulic fluid into the engine cowl where the high temp. environment aft of the vapor barrier can easily result in ignition. The most probable cause of case rupture is overpressure due to case drain flow restriction. Case drain flow monitors are available in MADARS.

A majority of pump failures are internal, not allowing extensive external fluid loss.

This area is covered by the engine fire fighting system.

CONCLUSION:

A ruptured hydraulic pump case can result in an engine fire.
Fire fighting is available.

PANEL RECOMMENDATION: (Use back if necessary)

MAC should emphasize the importance of noting case drain flow failure printouts from MADARS. Correction of the cause for each such failure message can help preclude engine fire.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: DATE: 30 Jan 1975 HAZARD NO: 9
NOMANCLATURE: Pylons

LOCATION: IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: Hydraulic Fluid, JP-4 & electrical wiring
STATEMENT OF HAZARD:

Ignition of leaking hydraulic fluid or JP-4.

DISCUSSION:

Bleed air ducts, electrical wires and electrical components are possible ignition sources. Fire has also spread through the fire wall from an engine fire in the past. Leakage of fuel from fuel lines has also been a problem in the past, but has apparently been corrected. The area is well ventilated. It will be protected by the FSS when installed.

CONCLUSION:

Probability of ignition low except for burn through of engine fire.

PANEL RECOMMENDATION: (Use back if necessary)

Expedite installation of new fire wall seal being developed under MIP SANBM 74-0096.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 14JGA DATE: 30 Jan 1975 HAZARD NO: 10
NOMANCLATURE: Flap Power Pack Assy

LOCATION: Center Rear Wing Beam
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: Hydraulic
STATEMENT OF HAZARD:

Power pack components overheat due to malfunction and ignite hydraulic fluid.

DISCUSSION:

Electrical components are solenoids and switches. System is protected by circuit breakers. Solenoids are explosion proof. The flap power pack is run intermittently for short periods so components would not overheat to temperature required for ignition. Area is vented so vapors would not likely build-up.

Hydraulic manifold has past history of failure. Although fluid would not likely ignite in immediate area, the volume of fluid and run off paths could provide fuel to other possible ignition sources. Manifolds have been redesigned. Units are being procured on priority basis but are scheduled for replacement on attrition basis. The hazards of spilled hydraulic fluid and operation with one system lost will remain until all units have been replaced.

Area will be protected by FSS.

CONCLUSION:

Probability of ignition is low. Hydraulics could provide fuel for other ignition source.

PANEL RECOMMENDATION: (Use back if necessary)

Replace manifolds as available rather than by attrition.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 45 J00 DATE: 30 Jan 1975 HAZARD NO: 11
NOMENCLATURE: 2/3 Power Transfer Unit (PTU)

LOCATION: Center Wing rear beam comp, fwd of aft troop comp.

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION

FLAMMABLE MATERIAL: Hyd fluid

STATEMENT OF HAZARD:

Failure of cartridge valves in PTU can spray hyd fluid throughout the wing rear beam compartment.

DISCUSSION:

Recently, failures have been experienced on the 2/3 PTU in which cartridge valve heads have been blown, spraying hyd fluid into the wing rear beam compartment. Possible ignition sources, discussed in other worksheets, include electrical wiring, flight control servos, and motor driven valves.

Similar failures have not been encountered on the 1/2 or 3/4 PTU's, which are located below the hyd reservoir level.

The possibility of the PTU overheating to an ignition temperature was considered negligible.

CONCLUSION:

This area is protected by the FSS. Known failure of the 2 to 3 PTU can provide a hyd fluid fuel constituting a fire hazard.

PANEL RECOMMENDATION: (Use back if necessary)

Continue investigation of this problem under MIP SANBM 74-0520.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 45 J00 DATE: 30 Jan 1975 HAZARD NO: 12
NOMANCLATURE: 1/2 and 3/4 Power Transfer Units (PTU)

LOCATION: FWD M.L.G. FAIRINGS
IGNITION TEMPERATURE DUE TO NORMAL OPERATION _____ MALFUNCTION
FLAMMABLE MATERIAL: Hyd fluid
STATEMENT OF HAZARD:

Failure of PTU's could result in spray of hyd fluid in the FWD M.L.G. FAIRING AREA.

DISCUSSION:

The 2/3 PTU is known to fail in such a manner as to spray hyd fluid (see worksheet on 2/3 PTU). If the 1/2 or 3/4 PTU fails in the same manner, it could provide fuel for an undetected fire.

These PTU's have not had failures of the same type as the 2/3 PTU. The probability of overheating to ignition temp is considered negligible.

FSS zone fire fighting will cover this area upon installation; however, until then, a fire could go undetected in this area.

CONCLUSION:

Although a fire is not likely to occur, flammables may be present due to PTU failure. Present methods would not detect such a fire.

PANEL RECOMMENDATION: (Use back if necessary)

- 1) T. O. 1C-5A-1 should be revised to add the following: If a PTU malfunction occurs during 1/2 or 3/4 PTU operation in flight, perform an inspection of the adjacent cargo compartment sidewall for indications of heat.
- 2) T. O. 1C-5A-2-3 should be revised to add the following: If a PTU malfunction occurs during ground operation, open access panel and inspect area for evidence of fire (prior to FSS).

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 42AAC DATE: 30 Jan 1975 HAZARD NO: 13
NOMENCLATURE: Aircraft Batteries

LOCATION: R. Fwd Cargo Compartment
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: Hydrogen/some cargo loads
STATEMENT OF HAZARD:

Battery explosion during charging.

DISCUSSION: These nickel cadmium batteries are very low capacity (5 ampers hour). The reliability of the cells used in the C-5 is very low. Apparently the load connected to these batteries when they are used as a sole power source is at or above their capability. Frequently when these batteries are being re-charged after use a condition called thermal runaway occurs. When this happens the electrolyte in the weakest cells boil off producing hydrogen gas. When the electrolyte level is depleted the cells overheat badly enough to melt their outer case and ignite the hydrogen gas in the battery case. To date the resultant explosions have been very small and usually are undetected until the battery is removed to the battery shop for failure or periodic (70 day) repair and capacity check. The batteries are located in and vented to the cargo compartment. There is little access to any fuel sufficient to sustain a fire with the exception of vapors from certain cargo loads.

DC power is required to operate the FSS. The batteries are the only source of DC power in an emergency where all the AC generators and the emergency generator are off/failed. The batteries will not provide sufficient power for operation of the FSS if not fully charged or at temperatures below -40°F. The batteries are used for other applications so would not necessarily be at full charge when needed. Installation of a charging rate control would decrease the likelihood of fire/explosion but would not solve the FSS power problem. A higher capacity battery would provide the FSS the needed electrical power and greatly reduce the likelihood of battery explosion.

CONCLUSION:

1. The batteries constitute a fire/explosion hazard.
2. The batteries are not adequate to assure FSS operation when needed.

PANEL RECOMMENDATION: (Use back if necessary)

Install higher capacity nickel cadmium or lead acid batteries.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: DATE: 30 Jan 1975 HAZARD NO: 14
NOMANCLATURE: Chin Drain System

LOCATION: Main Gear Well Only
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic Fluid
STATEMENT OF HAZARD:

Gear, tires, and wheel well being saturated with fluid from a leaking or broken drain line and fluid being ignited by a hot brake.

DISCUSSION:

Plastic drain lines in MLG wheel well areas are breaking and splitting due to altitude cold soaking, wind blast, and vibration. Even when properly installed, the lines sag between clamps providing low areas for collection of hydraulic fluid and/or water (accumulated from flushing down of hydraulic or cargo leaks inside cargo compartment). Water freezing at altitude may be cause of reported splitting. Accumulated hydraulic fluid, or fluid lost during flight from seal drains or overflowing reservoir, can flow onto wheels or brakes. The rubber tires will not absorb the fluid and only a limited amount can remain on the brake surface to be heated at ignition temp. Once the lines drained, there would be no further supply to sustain a fire. This area will eventually be protected by FSS. Actions are already in effect to detect possibility of hot brakes during taxi or take-off. Hot brakes on RTO or landing do not constitute a hazard in this case.

CONCLUSION:

There is a limited potential for fire in this area.

PANEL RECOMMENDATION: (Use back if necessary)

- 1) The straight runs of plastic tubing between MLG wheels should be replaced with a more durable tubing. Lightweight aluminum tubing might be suitable.
- 2) Until replacement is accomplished, T.O. 1C-5A-6 should be revised to require regular inspection of these lines for leaks, breaks, or splits; or collection of fluid at low points.
- 3) Until replacement is accomplished, T.O. 1C-5A-1 should be revised to add the following: In case of reservoir overflow during flight, monitor wheel well area for evidence of fire (prior to FSS).

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 42 GAA DATE: 30 Jan 1975 HAZARD NO: 15
NOMANCLATURE: Emergency Generator

LOCATION: Number two hydraulic service center L. cargo compartment.
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic Fluid
STATEMENT OF HAZARD:

Malfunction of the emergency generator contactor causing the emergency generator to overheat.

DISCUSSION:

The RAT deployment accumulator and several hydraulic lines are above the emergency generator. Leakage and fluid spills in this area are frequent. Pooling of fluid in and under the generator is possible. The emergency generator contactor connects the generator to the emergency bus when failure occurs in the AC or DC systems. This contactor has a history of failure even after Safety TCTO 1C-5A-1344 is accomplished. When the contactor fails, it connects the generator to AC power from other sources. This causes the generator to try to act as a motor, but it stalls because the hydraulic pressure is shut off to the hydraulic drive motor for the generator. This causes the generator windings to heat up to their melting point. The generator case temperature can get above the ignition temperature of hydraulic fluid. The generator is located behind soundproofing adjacent to the number two hydraulic system service center. This area is protected by smoke detection and will be protected by FSS, but a fire behind paneling would probably be quite large before it would be detected.

CONCLUSION:

The emergency generator contactor failures represent a source of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

1. Install warning system to indicate contactor failure.
2. Install contactor with higher reliability.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

13GGO/72GAO/13EED

WUC: DATE: 30 Jan 1975 HAZARD NO: 16
NOMANCLATURE: Crosswind Computer Radar Altimeter and Anti-Skid Control Box

LOCATION: L & R Cargo Area

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X

FLAMMABLE MATERIAL: Hydraulic fluid

STATEMENT OF HAZARD:

Possibility of malfunctioning the Crosswind Computer, Radar Altimeter or Anti-Skid Control box igniting a combustible.

DISCUSSION:

The crosswind computer could be saturated with hydraulic fluid from an overhead leak. Malfunction temperature of the cards is not known. The radar altimeter and the anti-skid control box have protective covers installed to prevent leaking hydraulic fluid from contacting them. All three units are located in the cargo area with smoke detection available. The crosswind computer and the anti-skid box are easily accessible for on board fire fighting equipment. The protective cover can easily be broken for access to the radar altimeters. Will be protected by FSS.

CONCLUSION:

A hazard exists in the crosswind computer if the temperature of the cards exceed the ignition temperature of fuel and oil vapors.

PANEL RECOMMENDATION: (Use back if necessary) 1. A study be conducted by ASD/ENJPF to determine the temperatures to which the failed printed circuit cards have been exposed. 2. If the ASD study indicates the failing cards are a serious heat source, the units should be shielded or otherwise isolated from fuel sources, similar to the Radar Altimeter and Anti-skid Control Box Shielding.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: DATE: 30 Jan 1975 HAZARD NO: 17
MANUFACTURE: Troop Compartment Grill

LOCATION:
IGNITION TEMPERATURE DUE TO NORMAL OPERATION: X MALFUNCTION:
FLAMMABLE MATERIAL: General Cargo
STATEMENT OF HAZARD:

Lighted cigarette drop onto cargo through the open grill!!.

DISCUSSION:

The system safety group has previously discussed this potential problem.

A cigarette can be dropped on to cargo below and go undetected and a fire could be started.

LGC has stated that any protective screen would restrict air flow that would be required during a rapid decompression.

CONCLUSION: This a potential fire hazard.

PANEL RECOMMENDATION: (Use back if necessary)

The crew should be included in the loadmasters briefing covering smoking restriction, in T.O. 1C-5A-1. MAC should enforce the existing requirement that crew and passengers not be allowed to smoke in the troop compartment unless they are seated in the troop area.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

NUC: 13 --- DATE: 30 Jan 1975 HAZARD NO: 18
NOMENCLATURE: MLG Extend/Retract Sys

LOCATION: MLG Wheel Wells
IGNITION TEMPERATURE DUE TO NORMAL OPERATION _____ MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic fluid
STATEMENT OF HAZARD:

Overheating of a MLG extend/retract component, such as a main gearbox assy clutch or electric motor, might ignite leaking hydraulic fluid.

DISCUSSION:

MLG components were evaluated as possible ignition sources in a failure mode. Only two components were identified as possibly achieving ignition temp. The hyd actuated clutch can slip, causing significant overheating. Recent modifications to the main gearbox are thought to have eliminated this slippage problem; however, a recent failure has been reported and a UR exhibit has been requested.

Failures on the electric motor have been through stalling and burning out; however, the motor is used only on emergency extension. Detection and fire fighting capability on the ground is considered adequate.

As discussed in the worksheet on MLG brakes, this area is now having detection installed and will receive fire fighting in FSS.

CONCLUSION: An overheated clutch in the main gearbox can serve as an ignition source.

Detection will be adequate with expedited installation of partial FSS, and fire fighting will be covered by full FSS.

PANEL RECOMMENDATION: (Use back if necessary)

- 1) MAC should continue inspection procedures established by MAC message DO/LG/IG 061715Z Jan 75 until fire detection is installed. 2) Cause of failure for modified clutch assembly should be determined and appropriate action taken.

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 13 E00/13 LAA DATE: 30 Jan 1975 HAZARD NO: 19
NOMENCLATURE: MLG Brakes & Tires

LOCATION: MLG Wheel Wells
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: Hyd fluid/Rubber tires
STATEMENT OF HAZARD:

Overheated brakes or tires igniting hyd fluid and/or tires.

DISCUSSION:

Brakes can generate temp enough for auto-ignition of hyd fluid. Tires can conceivably be ignited by scrubbing on runway. On ground detection and fire fighting is considered adequate, therefore, retracted gear is considered herein.

Hyd fluid is available from several sources: hyd drain lines, ATM panels, brake lines, etc. A failure or melting of any of these can ignite or feed an existing fire.

The detection portion of the FSS wheel well installation is being expedited. Interim procedures, required by MAC, include wheel well inspections after take-off.

San Antonio ALC is developing an ATM panel shield to reduce heat access to and fluid spray from, the panel. A mod proposal for installation of hyd fuses in the MLG anti-rotation system hyd lines is being considered by the AFLC Configuration Control Board for prevention of complete hyd system drainage into the wheel well.

CONCLUSION: Present inspection procedures are adequate to detect any such fire early. Detection system will allow discontinuation of insp. FSS zone fire fighting will provide protection when installed. Hyd fuses in all wheel well lines will limit fuel quantity if fire develops.

PANEL RECOMMENDATIONS: (Use back if necessary)

1) MAC should continue inspection procedures established by MAC message DO/LG/IG 061715Z Jan 75 until fire detection is installed. 2) Installation of fuses in any presently unprotected hydraulic lines in the landing gear system should be expedited.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 41CCE DATE: 30 Jan 1975 HAZARD NO: 20
NOMENCLATURE: Underfloor Heat System Fans

LOCATION: 3 Locations on left side under cargo compartment floor; F.S. 750

IGNITION TEMPERATURE DUE TO NORMAL OPERATION 1100

FLAMMABLE MATERIAL: 1750

STATEMENT OF HAZARD:

Aluminum fan blade tips could rub on fan housing, generating heat and ignition vapors in and/or surrounding the fan housing and ducts.

DISCUSSION:

The fan blades have approximately 0.003 inches tolerance (clearance) between tips and fan housing. Loose motor mounts or bad bearings could cause fan blade wobble, tip rub and subsequent friction heat. Flammable vapors from cargo spills, or aircraft fuel or hydraulic oil could be drawn through the environmental air ducts. If these two conditions exist in the same time interval, an explosion and/or fire could occur.

CONCLUSION:

A hazard can exist if fan fails in presence of flammable vapors.

PANEL RECOMMENDATION: (Use back if necessary)

An operational procedure should be added to T.O. 1C-5A-1 to require emergency depressurization to shut down underfloor fans if flammable vapors are present or suspected.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 41 JAE

DATE: 30 Jan 1975

HAZARD NO: 21

NOMANCLATURE: Wing Isolation Valves

LOCATION: Forward Wing Beam (Aft section of Crew Compartment)

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic Oil, gear box lubricant

STATEMENT OF HAZARD:

Flammable fluids could leak or drip down onto the valve motor or bleed air ducts, which are exposed.

DISCUSSION:

The two wing isolation valves and valve motor assemblies on the incoming bleed air ducts are mounted just above the floor in the environmental compartment. Several hydraulic lines are mounted above the isolation valves and could leak or develop pin-hole leaks spraying hydraulic fluid onto either isolation valve. Also, the leaking edge slat clutch-brake assembly is mounted directly above the right hand isolation valve. This clutch-brake provides protection in this area, when installed.

CONCLUSION:

The right hand wing isolation valve requires shielding to avoid contact with the flammable fluid. The left hand valve is not as serious a hazard.

PANEL RECOMMENDATION: (Use back if necessary)

Provide a cover over the right hand isolation valve. MIP SANBM 74-0223 should provide the required cover. This should be monitored until corrective action is taken.

REPLY/STATUS: (Use back if necessary)

MIP SANBM 74-0223 to provide a fireproof, grease proof cover over R.H. isolation valve should reduce the hazard.

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 14 JJB DATE: 30 Jan 1975 HAZARD NO: 22
NOMANCLATURE: SStat Proximity Cont Box

LOCATION: Fwd Bulkhead of Aft Troop Comp, inside wing rear beam area

IGNITION TEMPERATURE DUE TO NORMAL OPERATION — MALFUNCTION

FLAMMABLE MATERIAL: hydraulic fluid

STATEMENT OF HAZARD:

Overheating control box igniting leaking hydraulic fluid.

DISCUSSION:

A shorting circuit card inside the proximity control box might overheat to the ignition temp of hydraulic fluid. Actual temperature is unknown. Control box is a sealed unit.

Control box is virtually isolated; however, a spray or mist of hydraulic fluid might reach the unit. Such a leak would be easily detectable and accessible for on-board fire fighting if ignited. This area will be covered by FE1301 Halon fire suppressant when FSS is installed.

CONCLUSION:

FSS will adequately protect this area. Interim action not justified due to low probability of ignition. Inspection of area will detect leak/fire.

PANEL RECOMMENDATION: (Use back if necessary)

A periodic inflight inspection of aft troop compartment and wing rear beam area should be required on all missions.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

KJC: DATE: 30 Jan 1975 HAZARD NO: 23
NOMENCLATURE: Hazardous Areas

LOCATION: Forward and Aft Under Floor Compartments F.S. 664-1262 F.S. 1644-1964

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic Oil, Cargo spills

STATEMENT OF HAZARD:

Fire could occur as a result of flammables existing under the floor which would be ignited by malfunctions in a variety of electric motors, bleed air equipment or electronic components.

DISCUSSION:

MAC hauls a wide variety of types of flammable cargo which spill and leak through the cargo floor and pool between frames in the under floor area. Hydraulic leaks are common in these areas. This spillage and leakage may go undetected until the next major inspection, thus the flammable liquid condition could exist for a considerable time. If a malfunction or overheat condition would develop during this same time frame, a fire could very easily result. These under floor areas contain many components which could overheat. Each of these components are treated as separate items in this study and most have a slim chance of overheating. However, because of the large number and variety of these components, the chance that one will overheat during the lifetime of the entire fleet is extremely high.

CONCLUSION:

The forward and aft under floor areas must be protected from the chance of fire. The FSS will provide this protection, when installed.

PANEL RECOMMENDATION: (Use back if necessary)

- 1) An inspection requirement should be added to T.O. 1C-5A-1 and 1C-5A-6 to require inspection of the underfloor area when hydraulic fluid and/or flammable cargo spills into cargo compartment. 2) T.O. 1C-5A-1 should be revised to require a 781 entry any time hydraulic fluid and/or flammable cargo spills into the cargo compartment. This entry would require inspection of the underfloor area prior to next flight.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: DATE: 30 Jan 1975 HAZARD NO: 24
NOMANCLATURE: Fuel Tanks

LOCATION: Both wings

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION

FLAMMABLE MATERIAL: JP-4

STATEMENT OF HAZARD:

Fire and explosion.

DISCUSSION:

Leakage of fuel has been covered under other hazard areas. The tanks are susceptible to fire and/or explosion from fuel being ignited by one of several ignition sources. Some known ignition sources are lightning strike, static discharge, electrical arcing, penetration of tank by hot engine parts or incendiary gun fire and auto ignition from external fire. Lightning proof filler caps and improved component bonding and wiring installation practices have been incorporated in the C-5 fuel system. The FSS will protect this area.

CONCLUSION: The C-5A has the latest technology designed into the fuel system to reduce ignition sources, however, all ignition cannot be eliminated. The installation of the FSS cannot prevent fuel from burning which has leaked outside of a fuel tank if an ignition source is present but it can prevent fire and explosion inside the fuel tank regardless of ignition sources.

PANEL RECOMMENDATION: (Use back if necessary)

Continue with FSS installation.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 41 TCA DATE: 30 Jan 1975 HAZARD NO: 25
NOMANCLATURE: MADAR Cooling Fan

LOCATION: FS 470 IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: JP-4
STATEMENT OF HAZARD:

Electric motor could overheat or fan blade tips could rub on the fan housing generating heat which could ignite liquids or vapors.

DISCUSSION:

The electric motor is explosion proof and protected from overheat by both circuit breaker and internal thermal protection. Fan blade assemblies could work loose on their shaft or bearings could fail, allowing blade tip rubbing action which would generate heat.

CONCLUSION:

The amount of airflow around the motor/fan assembly is sufficient to preclude auto ignition of JP-4 vapors.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 11WFZ DATE: 30 Jan 1975 HAZARD NO. 26
NOMENCLATURE: Radome and Compartment

LOCATION: Aircraft Nose
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: Wiring Insulation
STATEMENT OF HAZARD:

Fire in the radome and radome compartment.

DISCUSSION:

The radome compartment contains numerous high power electronic systems but the only combustible available in the compartment to sustain an electrical or lightning strike fire is wiring insulation. The electrical/electronic systems have circuit protection and system malfunction indicators are installed. Any man-induced fuel should be discovered prior to flight.

CONCLUSION:

The radome is not considered to be a fire zone.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 44D00 DATE: 30 Jan 1975 HAZARD NO: 27
NOMENCLATURE: Cargo Lighting System

LOCATION: Cargo Bay
IGNITION TEMPERATURE DUE TO NORMAL OPERATION —
FLAMMABLE MATERIAL: Hydraulic Fluid/Oxygen
STATEMENT OF HAZARD:

Cargo lighting system igniting a combustible.

DISCUSSION:

A review was conducted of the following lighting components in the cargo bay; Dome lights, leading lights, curb lights, and curb light transformers. The normal face plate temperature is below 200°F. A malfunction could occur that could cause electrical arcing, but the components and wiring located where little combustible material is available. Area is currently protected by smoke detection system, and the FSS is to be installed. The area is accessible for use of on-board fire fighting equipment.

CONCLUSION:

These lights do not represent a significant source of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 44CYC DATE: 30 Jan 1975 HAZARD NO: 28
NOMANCLATURE: Hayloft/empennage lights and transformers

LOCATION: Hayloft/vertical stabilizers
IGNITION TEMPERATURE DUE TO NORMAL OPERATION _____ MALFUNCTION
FLAMMABLE MATERIAL: Hydraulic fluid
STATEMENT OF HAZARD:

Possibility of hayloft/empennage lights/transfomers igniting a combustible.

DISCUSSION:

The hayloft/empennage lights installation was reviewed and little chance was seen for hydraulic fluid to be available if a malfunction of the light or wiring occurred. The two transformers located on either side of the empennage access ladder could be in the path of hydraulic fluid leakers above them. The operating temperature of the transformers is approximately 285°F and malfunction temperature approximately 400°F. Adequate ventilation is available during flight to prevent ignition.

CONCLUSION:

Little hazard is expected in this area.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 71CMF/66A00 DATE: 30 Jan 1975 HAZARD NO: 29
NOMENCLATURE: Loran Ant. Coupler and CDPIR

LOCATION: Horizontal Stabilizer (See Discussion)
IGNITION TEMPERATURE DUE TO NORMAL OPERATION — MALFUNCTION
FLAMMABLE MATERIAL: Hydraulic Oil
STATEMENT OF HAZARD:

Malfunction of printed circuit may generate enough heat to ignite hydraulic oil mist.

DISCUSSION:

The Loran Antenna Coupler is located in the nose bullet of the horizontal stabilizer center body and could be hit by a spray of hydraulic oil from a failure of the pitch trim hydraulic system. The overheat temperature is unknown but it would only occur for a few seconds and would have to happen at the same time that the hydraulic system malfunction occurred. This area is well vented and it is unlikely that the hydraulic oil temperature could be raised to the fire point.

The CDPIR is in the upper surface of the afterbody of the horizontal stabilizer centerbody. The components of this unit are housed in an enclosed airfoil which is in turn shielded from the open compartment which is well vented. It is unlikely that oil mist could get to the electrical/electronic components.

CONCLUSION:

The likelihood of a hazard existing in this area is very low.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 61ADD DATE: 30 Jan 1975 HAZARD NO: 30
NOMENCLATURE: H. F. Transmitter

LOCATION: Approximately FUS STA 2500 in upper portion of compartment
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic oil
STATEMENT OF HAZARD:

Electrical ARC from antenna feed through or overheat from couplifier unit could possibly ignite a combustible.

DISCUSSION:

Leakage of hydraulic oil from a failure in the pitch trim actuator system could run down the leading edge of the vertical stabilizer into the area where the antenna leads go to the couplifier unit. The couplifier unit is below the deck so that it is improbable that oil would get in contact with the unit. There is no source of heat in the antenna compartment to elevate the temperature of the oil to the fire point where an arc could ignite it.

CONCLUSION:

The probability of a hazard existing in this area is very low.

PANEL RECOMMENDATION: (Use back if necessary)

None.

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 13LAE/13LCE DATE: 30 Jan 1975 HAZARD NO: 31
NOMANCLATURE: MLG/NLG Wheel Bearings

LOCATION: Wheel Wells
IGNITION TEMPERATURE DUE TO NORMAL OPERATION — MALFUNCTION
FLAMMABLE MATERIAL: Hyd fluid/rubber/grease
STATEMENT OF HAZARD:

Overheating due to failed bearings might ignite hyd fluid, grease, or tires.

DISCUSSION:

Failed bearings are known to have a potential for overheating in failure. On landing, such overheating can be detected and combatted adequately.

In flight, such significant overheating of MLG bearings should be detected by current MAC directed inspections. NLG bearing problems should be detectable during taxi operations before reaching excessive temp. Installation of the FSS will provide adequate detection/fire fighting capability.

No significant failure problems have been encountered on either NLG or MLG bearings.

CONCLUSION: A known failure mode has the potential to produce ignition temperatures in NLG or MLG wheel bearings; however, such failures are not documented as a C-5 problem.

FSS detection will detect any such fire, once installed.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 13E00/13J00 DATE: 30 Jan 1975 HAZARD NO: 32
NOMENCLATURE: NLG Extend/Retract/Kneel System

LOCATION: NLG Wheel Well

IGNITION TEMPERATURE DUE TO NORMAL OPERATION — MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic fluid

STATEMENT OF HAZARD:

Overheating NLG components igniting hydraulic fluid.

DISCUSSION:

No components in this system were found to be strong potential ignition sources. Short, intermittent actuation cycles on most components keep temps low. One electric motor is actuated only for emergency extension; another (kneel motor) only for ground operations; a third (gear box shift motor) has been shown to completely stall without reaching ignition temp.

CONCLUSION:

NLG extend/retract/kneel components do not represent probable ignition sources.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: DATE: 30 Jan 1975 HAZARD NO: 33
NOMANCLATURE: NLG Door Actuation System Components

LOCATION: NLG Wheel Well
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic Fluid
STATEMENT OF HAZARD:

Overheating components igniting hydraulic fluid.

DISCUSSION:

No components in this system were thought to be strong potential ignition sources. Short, intermittent activation cycles on most keep temp low. The door drive electric motors are used only for emergency extension and are circuit breaker protected.

The FSS will cover this area with zone fire fighting when installed.

CONCLUSION: The probability of the NLG door actuation components being ignition sources is low. Interim action before FSS installation is not justified due to low ignition probability.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WIC: 13GEU/13GEW DATE: 30 Jan 1975 HAZARD NO: 34
NOMANCLATURE: MLG Position Transmitter & Crosswind Transducer (LVDT)

LOCATION: MLC Wheel Wells
IGNITION TEMPERATURE DUE TO NORMAL OPERATION _____ MALFUNCTION X
FLAMMABLE MATERIAL: Hyd Fluid
STATEMENT OF HAZARD:

Overheated position transmitter or LVDT igniting leaking hyd fluid.

DISCUSSION:

The position transmitter and LVDT are both circuit breaker protected, and are enclosed in a large heat sink that would dissipate heat.

LVDT would be utilized only for short periods of time for landing or taking off. The units will be protected by the FSS.

CONCLUSION:

Position transmitter and LVDT do not present a significant ignition source.

PANEL RECOMMENDATION: (Use back if necessary)

None.

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 13 HOO

DATE: 30 Jan 1975

HAZARD NO: 35

NOMANCLATURE: MLG Hyd Kneeling System

LOCATION: MLG Wheel Wells

IGNITION TEMPERATURE DUE TO NORMAL OPERATION

MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic fluids

STATEMENT OF HAZARD:

Overheated kneeling system components igniting hydraulic fluid.

DISCUSSION:

Kneeling system components would be operated in flight only in an emergency.
Normal operation is on the ground.

Detection and fire fighting on the ground is considered adequate.

This area will be protected by the FSS.

CONCLUSION:

The hydraulic kneeling system does not represent a significant source of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: Various WUC's DATE: 30 Jan 1975 HAZARD NO: 36
NOMANCIATURE: Landing Grear Sequence Control Panels

LOCATION: NLG-RE lwd Cgo Comp. MLG-RT & Lt side Cntr of Cgo Comp.
IGNITION TEMPERATURE DUE TO NORMAL OPERATION HALFUNCTION X
FLAMMABLE MATERIAL: Hyd Fluid
STATEMENT OF HAZARD:

Overheating sequence control panel igniting leaking hyd fluid.

DISCUSSION:

A landing gear sequence control panel might overheat to ignition temperature of hyd fluid due to a shorted circuit card. Actual temp is unknown.

Panels are sufficiently sealed to prevent hyd fluid from dripping/running onto it from above. A spray or mist of hyd fluid might reach it from the front, but such a leak would be readily detectable.

This area will be covered by FE1301, Halon fire suppressant. Any fire would be readily detectable and accessible for on-board fire fighting.

CONCLUSION:

FSS will adequately protect this area. Interim action not justified due to negligible probability of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: N/A DATE: 30 Jan 1975 HAZARD NO: 37
NOMANCLATURE: AFT M.L.G. Fairings

LOCATION: MLG Fairings Aft of Wheel Well, Inb'd & Aft of APU Compartment
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic Oil
STATEMENT OF HAZARD:

Hot air ducts, shutoff valve or APU exhaust could ignite hydraulic oil.

DISCUSSION:

The supply, case drain and pressure lines from the ATM driven pump pass through this compartment. A leak from one of these lines could spray on the hot air ducts or valve. Hazard No. 53 covers the ignition hazard of hot air ducts and Hazard No. 56 covers the ignition hazard of the S.O. valve. There is no direct line of sight from the hydraulic lines to the APU exhaust duct, therefore the likelihood of getting hydraulic oil on the duct is very low. The duct is insulated such that the surface should not exceed 500°F. This area will not be protected by the F.S.S.

CONCLUSION:

The likelihood of a fire hazard existing in this compartment is very low.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: N/A DATE: 30 Jan 1975 HAZARD NO: 38
NOMENCLATURE: Unprotected Area

LOCATION: Left & Right of Nose Landing Gear Area F.S.: 524-664
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic Fluid
STATEMENT OF HAZARD:

Leaking hydraulic fluid could puddle in these two areas, and create a potential fire hazard.

DISCUSSION:

Compartments on either side of the nose landing gear well are enclosed and separated by an underfloor structural cross member from the remainder of the forward underfloor area. Inspection access to these areas is limited to removal of the floor panels. Detection of a fire in either of these areas would be difficult, particularly because the Fire Suppression System will not extend into these unpressurized areas. There are no ignition sources in this area.

CONCLUSION:

This area is not considered to be a fire zone.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: Various WUC's DATE: 30 Jan 1975 HAZARD NO: 39
NOMENCLATURE: Fit Contl Hyd Shutoff Valves in Aileron, Spoiler, Rudder & Elcyator Servo Manifolds.
LOCATION: Aft wing beams, horiz and vert stab rear beams
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: Hyd Fluid
STATEMENT OF HAZARD:
Hydraulic fluid leakage or spray from pin hole in lines with electrical wires in same area could produce fire.

DISCUSSION:

Flight control hyd shutoff valves are electric motor operated to the open position during flight. These motors are enclosed and protected by circuit breakers. Power is applied during flight to open valves. These electrical wires are so located that probability of shorted wire igniting a hyd fluid leak is very low because airflow in these areas is enough that circuit breakers would pop before sufficient heat could be generated to ignite hyd fluid.

CONCLUSION:

Hydraulic shutoff valves in these ventilated areas do not represent a significant source of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 14 AFT 52AJA DATE: 30 Jan 1975 HAZARD NO: 40
NOMENCLATURE: Aileron/Spoiler Cable Servo & Aileron/Spoiler Autopilot-Servo

LOCATION: Center Wing Rear Beam

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION

FLAMMABLE MATERIAL: Hydraulics

STATEMENT OF HAZARD:

Motors burn out, overheat, and ignite hydraulic fluid.

DISCUSSION:

Motors are sealed units, explosion proof, and protected with circuit breakers. With this protection they will not reach sufficient temperature to ignite hydraulic fluid. Area will be protected by FSS.

CONCLUSION:

Motors are adequately protected. Low probability of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

14LCJ/14LCL
WUC: 14.JEU/14.JEV DATE: 30 Jan 1975 HAZARD NO: 41
NOMANCLATURE: Slat/Flap Asymmetry Brakes

LOCATION: Outer Wing Front/Rear Beams
IGNITION TEMPERATURE DUE TO NORMAL OPERATION _____ MALFUNCTION
FLAMMABLE MATERIAL: JP-4
STATEMENT OF HAZARD:

Solenoids overheat and ignite leaking fuel.

DISCUSSION:

Solenoids are energized only during slat/flap operation when an asymmetrical condition occurs, a condition which will be detected and corrected. Limited time of operation and circuit breaker protection would prevent units reaching high temperature. JP-4 would not be likely to collect in flap area because of venting. Slat area is vented and subjected only to fuel tank leakage through the front beam.

CONCLUSION:

Solenoids are adequately protected. Low probability of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: Various WUC's DATE: 30 Jan 1975 HAZARD NO: 42
NONANCLATURE: Spoiler Servo and Actuators, Aileron Servo Assy, Aileron Trim
Actuator, and Aileron/Spoiler Mixer Ratio Shift Actuator
LOCATION: Outer Wing Rear Beam
IGNITION TEMPERATURE DUE TO NORMAL OPERATION
FLAMMABLE MATERIAL: Hydraulic, JP-4
STATEMENT OF HAZARD:

Electric components overheat and ignite hydraulic fluid or JP-4.

DISCUSSION:

Units contain motor operated shut-off valves, pressure switches, electro-hydraulic valves, LVDT's, and solenoids. Most of these components operate for short periods of time. All are protected with circuit breakers. Motors are explosion proof. Area on wing is well vented and at low temperature in flight. Vapors could collect on the ground but units would be generated only for short periods.

CONCLUSION:

The electrical components are adequately protected. Low probability of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 52AB- DATE: 30 Jan 1975 HAZARD NO: 43
NOMENCLATURE: Elevator Servo and Elevator PAC Servo

LOCATION: Horizontal Stabilizer Rear Beam

IGNITION TEMPERATURE DUE TO NORMAL OPERATION

MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic

STATEMENT OF HAZARD:

Electric components overheat and ignite leaking hydraulic fluid.

DISCUSSION:

Electric components include motor operated shutoff valves, pressure switches, electro-hydraulic valves, solenoids, linear variable displacement transducer (LVDTs). Some components are used only intermittently. All have circuit breaker protection. Locations are in area of high air flow except during ground operation during which operation would be of short duration.

CONCLUSION:

Electrical components are adequately protected. Possibility of heating hydraulic fluid is limited. Probability of ignition is low.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 14GAJ DATE: 30 Jan 1975 HAZARD NO: 44
NOMENCLATURE: Pitch Trim Actuator

LOCATION: In Top of Vertical Stabilizer
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic
STATEMENT OF HAZARD:

Electric components fail, overheat, and ignite hydraulic fluid.

DISCUSSION:

Electrical components are solenoids. All have circuit breaker protection.
Units should not overheat to temperature necessary to ignite hydraulic fluid.

CONCLUSION:

Electrical units are adequately protected. Probability of ignition is limited.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: various WUC's DATE: 30 Jan 1975 HAZARD NO: 45
NOMENCLATURE: Rudder Servo Assemblies, Rudder Trim Actuator, Rudder Limiter Actuator
LOCATION: Vertical Stabilizer Rear Beam
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic
STATEMENT OF HAZARD:

Electric components fail, overheat, and ignite leaking hydraulic fluid.

DISCUSSION:

Electric components include motor operated shutoff valves, pressure switches, electrohydraulic valves, LVDT's and solenoids. Most units are used intermittently for short duration. All have circuit breaker protection. Units are located in area of high air flow during flight. On the ground, units would be energized for short period of time.

CONCLUSION:

Electrical units are adequately protected. Limited probability of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 14LCD/14JCS DATE: 30 Jan 1975 HAZARD NO: 46
NOMANCLATURE: Slat Clutch/Brake Assy & Slat Decoupler

LOCATION: Center Wing Frt Beam/Center Wing Rrnt Beam

IGNITION TEMPERATURE DUE TO NORMAL OPERATION

MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic fluid

STATEMENT OF HAZARD:

Component overheats due to malfunction and ignites leaking hydraulic fluid.

DISCUSSION:

Units are on for limited duration but solenoids in clutch/brake are energized continuously. Unit has circuit breaker protection. Solenoids should not get hot enough to ignite hydraulic fluid. Area will be protected by FSS.

Decoupler bearings could fail, get hot and ignite hydraulic fluid leaking from adjacent installations. No cases of this in service. Rotational speed is low (1600 rpm) and duration of operation (less than 1 minute) would be too short a time to permit sufficient temperature generation. Area will be protected by FSS.

CONCLUSION:

Probability of ignition is extremely low.

PANEL RECOMMENDATION: (Use back if necessary)

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 52AE DATE: 30 Jan 1975 HAZARD NO: 47

NOMENCLATURE: Elev. Autopilot Servo & VFU

LOCATION: Cargo compartment ceiling under co-pilot

IGNITION TEMPERATURE DUE TO NORMAL OPERATION

MALFUNCTION X

FLAMMABLE MATERIAL: hydraulics

STATEMENT OF HAZARD:

Component overheats due to malfunction and ignites leaking hydraulic fluid.

DISCUSSION:

The elevator autopilot servo and the variable feel unit both have electric motors. The motors are explosion proof and have circuit breaker protection. Experience has been that the failed motors would not reach temperatures sufficient to ignite hydraulic fluid before opening the circuit breaker.

The VFU also contains pressure switches but these cannot overheat to ignite hydraulic fluid. Area will be protected by FSS installations.

CONCLUSION:

The motors are adequately protected.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WJC: Various WUC's DATE: 30 Jan 1975 HAZARD NO: 48
NOMANCLATURE: Motor Driven Hydraulic Valve

LOCATION: Engine and ATM Hyd Suction Lines
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic Fluid/JP-4
STATEMENT OF HAZARD:
Overheating electric drive motor igniting leaking hyd fluid or JP-4.

DISCUSSION:

A dual failure of (1) electric drive motor on the motor driven valve and (2) a hydraulic or JP-4 leak in the same area might result in a fire.

Motors are explosion proof and are circuit breaker protected on input side. Experience has been that these motors open the circuit breakers or burn out quickly enough that extensive external heat is not generated.

CONCLUSION:

Motors are adequately protected. Low probability of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC:45AEB/CEB/EEB/GEB DATE: 30 Jan 1975 HAZARD NO: 49
NOMANCLATURE: Hydraulic Boost Pumps

LOCATION: Hyd. Service Center

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X

FLAMMABLE MATERIAL: Hydraulic Fluid

STATEMENT OF HAZARD:

Hydraulic pump malfunction and overheat igniting hyd. fluid.

DISCUSSION:

Pump failures have not generated sufficient temp. to ignite hyd. fluid.

If a fire were to develop, early detection is most likely and the fire would be easily accessible for fire fighting purposes. Area will be protected by the FSS.

CONCLUSION:

This condition is not a critical fire hazard.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 45AEC/GEC DATE: 30 Jan 1975 HAZARD NO: 50
NONANCLATURE: Electric Suction Boost Pump

LOCATION: #1 & #4 Hydraulic Service Center

IGNITION TEMPERATURE DUE TO NORMAL OPERATION

MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic fluid

STATEMENT OF HAZARD:

Electrical Boost pump failure could ignite hyd. fluid.

DISCUSSION:

The pump is protected with circuit breakers. The pump has no known history of fire in the C-130, 141, and C-5 aircraft.

The probability of overheat to sufficient temperature to ignite hydraulic fluid is low. If a fire started, early detection would be likely, and the fire would be easily accessible for fire fighting purposes. FSS will protect this area.

CONCLUSION:

This condition is not a critical fire hazard.

PANEL RECOMMENDATION: (Use back if necessary)

None.

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 45LE- DATE: 30 Jan 1975 HAZARD NO: 51
NOMANCLATURE: Ram Air Turbine (RAT) Assy

LOCATION: RAT Compartment (LH Fwd MLG)

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION

FLAMMABLE MATERIAL: Hyd fluid

STATEMENT OF HAZARD:

Hydraulic fluid leakage or spray from a pin hole in line while unit is retracted in compartment, or hyd pressure reverse flow driving pump.

DISCUSSION:

The possibility exists of driving the RAT pump in reverse from NR2 hyd system pressure while unit retracted in compartment. Before hyd pressure can be generated to reverse drive the pump, a pressure line check valve, control regulator valve, and return system solenoid/manual valve must be activated. If this sequence occurred, the RAT would extend. If reverse flow drove the RAT backwards, while extended in the airstream which would try to drive the RAT forward, the RAT would overheat and/or rupture hydraulic lines. There is no electrical power in the area; extend switch is ground only.

CONCLUSION:

Reverse drive of RAT pump is not probable due to the multiple failure modes involved.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 41APC DATE: 30 Jan 1975 HAZARD NO: 52
NOMANCLATURE: Cargo Compartment Recirculating Fan

LOCATION: Wing Front Beam F.S. 1107

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic Oil, JP-4 vapors

STATEMENT OF HAZARD:

Electric motor could overheat or fan blade tips could rub on fan housing generating heat which could ignite liquids or vapors.

DISCUSSION:

The electric motor is explosion proof and protected from overheat by both circuit breaker and internal thermal protection. Fan and motor could come loose in its mounts, allowing blade tip rubbing action which would generate heat.

Hydraulic oil from above fan could spray/drip onto overheated fan.

The installation will be adequately covered by the Halon 1301 FSS, when installed.

CONCLUSION:

The motor is adequately protected. The fan tip rubbing will drag motor rpm down, increasing amperage which will blow circuit breaker or internal thermal protection.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: Various WUC's DATE: 30 Jan 1975 HAZARD NO: 53
NOMANCLATURE: Hot Air Bleed Ducts

LOCATION: See DISCUSSION

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic oil/JP-4

STATEMENT OF HAZARD:

Ignition of flammable material by hot surface of ducts or leakage of hot air.

DISCUSSION:

The hot air bleed ducts run from the engine nacelles up the pylon leading edge and from outboard pylons in the wing leading edges to the fuselage and across the fuselage forward of the wing front beam. Also a line runs from the L. H. APU compartment across underfloor to the R. H. APU and upward into the cargo compartment where it runs along the R. H. cargo wall forward to the wing front beam station and thence upward to tie into the cross ship duct in the environmental compartment. It takes a double failure, pressure aug. valve and pylon S. O. valve, for the air in this duct to reach a temperature above 600°F (APU Max. temp 540°F) and both of these failures are detectable. All of the ducts and connectors are insulated to surface temperature below 400°F. All of the mechanical connections of these ducts have overheat detectors set at 310°F to warn if there is excessive leakage.

There was no ignition obtained in tests conducted at Lockheed where hydraulic oil was exposed to bare ducts, on insulation, under insulation and soaked on frayed insulation, even though the temperature of the air in the ducts exceeded the normal max (600°F). Reference Appendix D.

CONCLUSION:

The likelihood of hot air ducts on the C-5 being a fire hazard is very low.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 41ATE DATE: 30 Jan 1975 HAZARD NO: 54
NONANGLATURE: Turbine driven cooling fan

LOCATION: Wing leading edge, inboard of slats
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hydraulic oil
STATEMENT OF HAZARD:

Tip rub of fan could heat external surfaces to a point it would ignite hydraulic oil.

DISCUSSION:

This fan is powered by a hot air tip driven turbine which exhausts overboard through a duct and is operated to provide cooling air for the primary and secondary heat exchangers at speeds below .3MACH No. The unit is located in a sealed plenum which would have to have a massive structural failure to allow hydraulic oil to come in contact with the unit. There are hydraulic lines in the wing leading edge air of the plenum. Failure of the plenum would be detectable as an air conditioning overheat and the hydraulic failure would result in a system fluid loss.

CONCLUSION:

The likelihood of a hazard existing in this area is very low.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 41AWF DATE: 30 Jan 1975 HAZARD NO: 55
NOMANCLATURE: Cooling Turbine

LOCATION: On side walls of environmental compartment
IGNITION TEMPERATURE DUE TO NORMAL OPERATION — MALFUNCTION
FLAMMABLE MATERIAL: Hydraulic Oil
STATEMENT OF HAZARD:

The hot surfaces of the unit could ignite hydraulic oil.

DISCUSSION:

These hydraulic lines coming into the compartment from the wing leading edges turn aft under the wing box immediately and are shielded from the turbine units by cargo air conditioning distribution ducts. There is however a direct line of sight from the hydraulic lines attaching to the slat gear box to both L.H. and R.H. units. The L.H. unit is approximately 8 ft from the gear box and the R.H. unit is about 5 ft away. The normal max operating surface temperature of the unit is below 600°F; however, if the unit is allowed to operate at overspeed/overtemp for an extended length of time (30 min) the compressor scroll could reach a temperature exceeding 700°F. The unit is designed to preclude continued operation at an overtemp condition by fusing the turbine wheel where it will fail in a tri-hub burst at 75,000 rpm. Containment of this failure has been demonstrated. Failed bearings could result in wheel tip rub on either the turbine or compressor scrolls and a prolonged operation with this failure could result in surface temperatures up to 1300°F. Failures of this type would normally be prevented by a prior tri-hub burst of the turbine wheel.

The area will be protected by FSS.

CONCLUSION:

Due to the separating distance between the source of hydraulic oil and the units and the low probability of the surface temperatures of the units reaching an ignition temperature, the likelihood of these units being a fire hazard is very low.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: Various WUC's DATE: 30 Jan 1975 HAZARD NO: 56
NOMENCLATURE: Motor Driven Environmental Control Valves

LOCATION: Various Locations

IGNITION TEMPERATURE DUE TO NORMAL OPERATION

MALFUNCTION

FLAMMABLE MATERIAL: Hydraulic fluid/JP-4

STATEMENT OF HAZARD:

Electric motors could fail internally, overheat and ignite leaking hydraulic fluid or JP-4.

DISCUSSION:

The motors which operate the environmental control system control valves could fail due to bearing failure or a short circuit. The motors could also fail to stop running due to a malfunctioning limit switch, in which case the motor would stall out, drawing excessive current. The overheated motor could vaporize combustible fluids, igniting the fuel/air vapors. However, these electric motors are explosion proof, protected by circuit breakers, and contain an internal thermal sensor. The overheat condition would only exist until the internal thermal protective device or the circuit breaker opens.

CONCLUSION:

Electric motors are adequately protected from a continuous overheat condition.

PANEL RECOMMENDATION: (Use back if necessary)

None.

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 41 GEA/GEB DATE: 30 Jan 1975 HAZARD NO: 57
NOMANCLATURE: Pressurization Outflow Valves

LOCATION: Rt Aft Cgo Comp
IGNITION TEMPERATURE DUE TO NORMAL OPERATION _____ MALFUNCTION X
FLAMMABLE MATERIAL: Hyd Fluid
STATEMENT OF HAZARD:

Overheated motor igniting hyd spray or mist.

DISCUSSION:

Failure of a motor might cause motor overheating to ignition temp. Hyd fluid spray or mist might reach the unit; however, such a leak is easily detectable.

Motor is explosion proof and protected by circuit breakers on the input side. Motor is enclosed and isolated. Overheating is not expected to raise external temp. to ignition temp.

This area will be covered by FE1301 Halon fire suppressant when FSS installed.

CONCLUSION:

Motor is adequately protected. FSS will adequately protect this area. Interim action not justified due to low probability of ignition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: Various WUC's DATE: 30 Jan 1975 HAZARD NO: 58
NOMENCLATURE: Motor Drive Duct Shut Off Valve

LOCATION: Wing Aft Beam/ Wing Root / Dry Bay
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: JF-4
STATEMENT OF HAZARD:

Electric motors could fail internally, overheat and ignite leaking fuel.

DISCUSSION:

The motors which drive fuel valves open and closed could fail due to bearing failure or a short circuit. This could cause the motor to overheat, vaporizing fuel and igniting the flammable vapors. However, these motors are explosion proof, protected by circuit breakers, and contain an internal thermal sensor. The overheat condition would exist until the internal protective device opens or circuit breaker trips. The wing root dry bay will be covered by FSS.

CONCLUSION:

Electric motors are adequately protected from a continuous overheat condition.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 46HAE DATE: 30 Jan 1975 HAZARD NO: 59
NOMENCLATURE: SPR Drain Line Pumps

LOCATION: Forward M.L.G. Fairing
IGNITION TEMPERATURE DUE TO NORMAL OPERATION
FLAMMABLE MATERIAL: JP-4/Hydraulic Oil
STATEMENT OF HAZARD:

A malfunctioning motor could ignite a combustible from arcs or overheated case.

DISCUSSION:

There are hydraulic lines in this cavity but the lines are not pressurized at the time this pump is utilized. JP-4 fuel lines/couplings could leak and create an explosive mixture in the compartment while the pump is in operation. The pump motor is explosion proof and is protected with circuit breakers. This pump has been used on C-130, and C-141 aircraft, as well as C-5's, and there have been no known malfunctions which would have created this hazard. The pump is used only after ground refueling operations and the area is manned during this time. The FSS will protect this compartment when installed.

CONCLUSION:

The likelihood of this being a hazard is very low.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary)

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: Various WUC's DATE: 30 Jan 1975 HAZARD NO: 60
NOMENCLATURE: FWD/AFT Ramp Controls and FWD/AFT Lighting Control Panels

LOCATION: Cred Entrance Door and Left Troop Door
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X
FLAMMABLE MATERIAL: Hyd fluid
STATEMENT OF HAZARD:

Spraying or leaking hyd fluid on electrical components.

DISCUSSION:

Hydraulic lines could rupture and saturate electrical control panels with hydraulic fluid resulting in hydraulic fluid being ignited.

This malfunction would be easy to detect, and if a fire starts, it is accessible for use of onboard fire fighting equipment.

These areas will be protected by FSS when installed.

CONCLUSION:

These areas are well vented and easily accessible. The probability of a fire is low due to the lack of sufficient heat to ignite hydraulic fluid.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary) .

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

MIC: 12 CAG DATE: 30 Jan 1975 HAZARD NO: 61
NOMENCLATURE: Cargo Winch

LOCATION:

IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION X

FLAMMABLE MATERIAL: Flammable Fluids (Hyd., MoGas, Diesel).

STATEMENT OF HAZARD:

Overheated cargo winch returned to the storage compartment which has had flammable fluids spilled into the compartment.

DISCUSSION:

A flammable fluid could be spilled into the winch compartment and not cleaned up. If, during winch operation, the winch overheats and it is not detected, a fire could occur. Loadmaster procedures require a survey of the winch compartment for foreign material prior to winch operation. There is no requirement to observe the winch during operation.

CONCLUSION:

A hazard exists if the compartment is not adequately cleaned.

PANEL RECOMMENDATION: (Use back if necessary)

1) Until release of, and compliance with, TCTO 1C-5A-1740, which will provide drain holes in the winch compartment, MAC should emphasize the need for cleaning the compartment after any fluid spillage; and the need for thorough inspection prior to winch operation. 2) Instructions should be added in T.O. 1C-5A-9, requiring observation of winch during operation.

REPLY/STATUS: (Use back if necessary)

OPERATIONAL FIRE HAZARDS WORKSHEET

WUC: 12GCK DATE: 30 Jan 1975 HAZARD NO: 62
NOMENCLATURE: Static Line Retriever Winch

LOCATION: Center of Cargo Comp.
IGNITION TEMPERATURE DUE TO NORMAL OPERATION — MALFUNCTION X
FLAMMABLE MATERIAL: Hyd Fluid
STATEMENT OF HAZARD:

Overheat or electrical short in winch igniting hyd. fluid leak.

DISCUSSION:

Failure of the winch can result in ignition of hyd fluid spray or mist. Unit is manned at all times during use; therefore any leak that could reach the unit would be immediately detected, and on-board fire fighting would be available, if ignition occurred.

This area will be covered by FE1301 Halon fire suppressant when FSS is installed.

CONCLUSION:

Due to constant manning, significant hazard does not exist.

PANEL RECOMMENDATION: (Use back if necessary)

None

REPLY/STATUS: (Use back if necessary).

N/A

OPERATIONAL FIRE HAZARDS WORKSHEET

WJC: 47000 DATE: 30 Jan 1975 HAZARD NO: 63
NOMENCLATURE: LOX Converter

LOCATION: LOX Compartment between fwd and aft wheel well, left side
IGNITION TEMPERATURE DUE TO NORMAL OPERATION MALFUNCTION
FLAMMABLE MATERIAL: JP-4, Hydraulic Fluid, other combustible materials
STATEMENT OF HAZARD:

Leaking or ruptured LOX/gaseous oxygen system components will lower the ignition temperature of most flammable materials, and intensify any fire.

DISCUSSION:

The aircraft oxygen system is isolated from most sources of fuel and protected by wrapped insulation. However, a leaking oxygen line, valve or regulator would introduce pure oxygen into most of the fire zones in the fuselage. The presence of oxygen will lower the flash point and ignition of leaking fuel and other combustibles. A fire involving oxygen enriched atmosphere will produce a very intense fire with an increased burning rate and may cause the combustion of materials that would not normally burn in a standard atmosphere. The oxygen system has a manual emergency shutoff valve mounted on the pressure skin inside the oxygen converter compartment with the valve handle protruding inside the cargo compartment. In the event of an oxygen fed fire, a crew-member must go to the left center of the cargo compartment to close the emergency shutoff valve. .

CONCLUSION:

With the existence of many hot components throughout the fuselage, the crew should have the capability to remotely isolate the oxygen system from the fire.

PANEL RECOMMENDATION: (Use back if necessary)

A study should be made to determine the feasibility of installing a remote oxygen shut-off capability mounted on the Flight Engineer's Console. Accomplish modifications recommended as a result of the study.

REPLY/STATUS: (Use back if necessary)

APPENDIX F
FSS COVERAGE AND CAPABILITIES

The FSS protects the following areas: (See attached Figures)

1. Fuel tanks
2. Cargo compartment
3. Avionics and Guidance (A&G) equipment compartment
4. The center wing section, including the Environmental Control System (ECS) equipment, wing box and flap control equipment
5. The wing dry bays and wing and pyion leading edges.
6. The main and nose wheel wells
7. The forward and aft under floor areas
8. The PTU compartments in the main landing gear pod

The fuel tanks and their corresponding vent systems are protected against fire and explosion by nitrogen inerting. The principle of inerting is to maintain an oxygen concentration in the fuel tanks and vent lines below that which is necessary to support combustion. Nitrogen, which is an inert gas, is used to replace the oxygen in both the fuel and the vapor spaces in the fuel system. By the use of vent valves and nitrogen regulators, pressures within the tanks are maintained at a slightly higher pressure than outside ambient pressure to prevent the entry of air which would destroy the inert atmosphere. Nitrogen is stored onboard the aircraft in the liquid form in vessels called dewars. The system operates automatically at all times with or without electrical power and whether the aircraft is attended or unattended. Testing

showed the oxygen concentration in the tanks remained well below the 9% requirement during all phases of flight.

The cargo compartment, the avionics and guidance bay and the center wing section are considered manned areas and are protected by optical fire detectors and bromotrifluoromethane (Halon 1301) extinguishing agent. The detectors are activated by the infrared in the flame and cause fire warning lights to light. Halon 1301 is a freon agent similar to the Halon 1201 agent used in the present C-5 engine and APU fire fighting systems. It extinguishes fires by chemical reaction and is relatively safe to use in inhabited areas.

The wing and pylon leading edges, the dry bays, the PTU compartments, the wheel wells and the under floor areas are considered unmanned areas and are protected by thermal fire detectors, sometimes called continuous sensors, and liquid nitrogen (LN_2) extinguishing agent. The thermal detectors sense increases in temperature and at a predetermined temperature will cause a warning light to light. LN_2 is not as efficient an extinguisher as FE1301, but is used because it is already present for use in the inerting system and does not significantly increase weight. LN_2 extinguishes fires by suffocation and is, therefore, dangerous to use in inhabited areas. The LN_2 system has multi-discharge capability, whereas FE1301 only has one.

FSS fire indicator and fire fighting control panels are located at the flight engineer's station, at the aft loadmaster panel and in the nose wheel well (NWW). Each panel has a switch to arm the system. The NWW

(Pages 128 - 129 Blank)

panel is powered from the battery if no other electrical source is available. The indicator lights are an integral part of the discharge switch. Fire warning lights are also present on the pilot's and the flight engineer's annunciator panels.

The manned areas are separated into three zones, the A&G bay, the center wing area and the cargo compartment. The cargo compartment has 17 halon bottles containing 70 pounds of FE1301 each, the center wing has two 70-pound bottles and the A&G bay has one 10-pound bottle. A warning light/discharge switch for each zone is located on both the flight engineer's and the loadmaster's panels. The NM panel has one light/switch which will indicate a fire in any one of the three zones and discharge all 20 bottles when depressed.

The unmanned areas are separated into 12 zones. The zones are as follows:

1. Left wing dry bay, No. 1 pylon leading edge, wing leading edge between No. 1 and 2 pylons.
2. No. 2 pylon leading edge, wing leading edge between No. 2 pylon and the fuselage, and left wing root dry bay.
3. Right wing root dry bay, wing leading edge between the fuselage and No. 3 pylon, and No. 3 pylon leading edge.
4. Wing leading edge between No. 3 and No. 4 pylons, No. 4 pylon leading edge and the right wing dry bay.
5. The nose wheel well.
6. The forward underfloor (forward half of section between the main gear well and nose gear well).

7. The center underfloor (aft half of section between the main gear well and nose gear well).
8. Left main well wheel.
9. Right main well wheel.
10. Aft underfloor (aft of main gear well).
11. Left PTU compartment.
12. Right PTU compartment.

The flight engineer's panel has a warning light/discharge switch for each zone.

The loadmaster's panel has no indicators or switches for unmanned areas. The NWW panel has one indicator/switch for the two left wing zones, for the two right wing zones, the four zones forward of the main wheel well, except NWW (forward underfloor, center underfloor and both PTU compartments), and for the aft underfloor zone.

FE1301 will extinguish fires at concentrations of three or four percent; however, in order to assure complete extinguishing, the specification requires six percent concentration in the entire protected area within four seconds. The cargo compartment was the only manned area which did not meet the four second requirement during qualification testing. While most of the volume of the cargo compartment was under the specified time, several remote areas did not reach six percent until five seconds had elapsed. Due to the large volume of the cargo compartment and the necessity to keep the Halon containers out of the cargo envelope, this deviation was accepted. The specification also required, with exception of

the avionics bay, that the six percent concentration be maintained for a minimum of five minutes with the circulating fans off. Halon extinguishes fire within milliseconds once it reaches the proper concentration, but the five minutes allows the fire area to cool so reignition will not occur. The cargo compartment and the center wing box remained within acceptable levels far over the time requirement. The ECS compartment was slightly below the requirement and the aft wing spar area (flap control area) was well below it, approximately 26 second average. These early decreases in concentrations were due to the necessity to vent the areas to the cargo compartment to equalize pressures in case of a rapid decompression. Since blocking of the vent areas could not be safely accomplished, the deviations were accepted. The time to six percent in the ECS section was close enough to the time requirement that proper cooling will still take place. The aft wing spar area will have to be monitored with hand bottles after initial extinguishing. Also, it is felt that a fire in this area would propagate to the cargo compartment since the combustible in this area would be hydraulic fluid from the flap pack, which would run into the cargo deck through the large vents. The discharge of Halon in the cargo area as well as in the center wing would cause the concentration in the center wing to remain above six percent for the required time.

The avionics compartment time at six percent requirement was specified as ten seconds. This is because the cooling fan in the compartment recirculates the air quite rapidly. Even if the circuit breaker for the fan

is pulled, an overboard valve opens which vents the pressurized compartment to outside ambient pressure which creates approximately the same recirculation when at altitude. This area also needs additional monitoring with an A-20 fire extinguisher until the source of the fire has been found and deactivated.

Halon 1301 has a toxic effect on humans at high concentrations. For this reason a maximum allowable concentration of ten percent was specified. In order to stay below this concentration in the cargo compartment as the volume of cargo increases, it is necessary to cut several bottles out of the firing circuit. A volume selector switch on the flight engineer's panel has three positions on it. The "Below 10,000 Cu Ft" position fires all 17 bottles. "The 10,000 to 20,000 Cu Ft" position fires 13 bottles and the "Over 20,000 Cu Ft" position fires nine bottles. The bottles that are not fired while at a higher volume selection can be fired at a later time, if necessary, by placing the selector switch on "Under 10,000 Cu Ft" and depressing the discharge switch again.

The detectors in the manned areas will detect all visible infrared (IR) on a 45 degree angle from the center line of the detector (see attached figures). This creates a 90 degree cone of vision from the detector. The detectors are installed so that they scan the largest fire susceptible areas with the center line detection as much as possible toward the most likely ignition sources. Two detectors in the ECS area do not cover areas behind ducting, but flames are expected to appear from behind the ducting. One detector in the center wing box will detect any flame where combustibles

are liable to be in this area. Three sensors in the aft center wing spar area encompass the entire hydraulic control section. The A&G bay has three detectors which scan all electronic equipment and are especially effective when the compartment lights are off. The 30 detectors in the cargo compartment are located on the ceiling, 11 on the right side, seven in the middle and 12 on the left side. They are aimed to detect fires between cargo and the fuselage on the left and right sides, in the center between cargo pallets, across the top of cargo, and the entire area when no cargo is onboard.

Nitrogen gas must reduce oxygen concentration below 12 percent to extinguish fire.

The specification requires the oxygen concentration be below 10 percent within 10 seconds of discharge. Testing in a simulated wing root dry bay and an aft underfloor section, showed that fires were detected within 22 seconds after ignition and extinguished within 7.5 seconds of detection. (This was igniting a four square foot pan of JP-4 fuel). NOTE: When a nitrogen discharge button is depressed on the MM panel LN_2 discharges until depleted or turned off. The other discharges are timed. In the unmanned areas, the thermal detector wires, which are 20, 30, and 43 feet in length are located to best measure the average temperature in a protected area and are looped back through areas where the most probable ignition sources exist. The sensors in the wing areas which are subjected to solar heating, will give a fire indication at an average temperature of 255°F. The entire underfloor area, which is not subject to solar heating, triggers at 160°F.

Areas unprotected by FSS and rationale for no coverage

The following areas are not protected by the FSS:

1. The empennage.
2. The wing flap and aileron wells.
3. The flight deck, including crew rest and courier compartment.
4. The troop compartment.
5. The main landing gear pod aft of the wheel wells, between the APU compartments and the pressure vessel.
6. The underfloor compartments to the left and right of the nose wheel well.
7. Radome.
8. Wing tips.
9. Under the wing-to-fuselage airings and under the lobe-to-lobe panels.
10. Wing leading edge outboard of outboard engines.

The empennage has an extremely large volume and is well vented. These factors plus the cold temperatures encountered in flight and the distant proximity of ignition sources to flammable fluids make the possibility of combustion occurring, or maintaining combustion if combustion does occur, very small. The same factors make the possibility of getting enough extinguishing agent to a fire with a fixed system even smaller.

The wing flap and aileron wells are well ventilated and have a fairly large volume. Also ignition sources are few, particularly in the flap well. This area is also cold during flight. During the period when ignition sources are most likely to be energized, the flaps are extended which negates any protection available. The flight deck, crew/test area, courier compartment

and troop deck are not protected for several reasons. First, areas where combustion can occur are accessible with A-20 hand bottle. The majority of ignition sources, except for the flight deck, would result from human action and should be quickly detected and extinguished. The flight deck is usually occupied when ignition sources are present and fire would be quickly detected and extinguished. Another reason for omission of fixed fire fighting in these areas is that the loud noise and loss of visibility due to condensation which result from discharging Halon could be more of a flight hazard than a fire, particularly when inadvertently discharged. The aft main gear pod area was not protected because the possible ignition sources were well separated from the possible flammable fluid source. The bleed air lines in this area have overheat detectors to indicate line failure. The APU exhaust pipes come out the back of the APU compartments and the pressure and suction hydraulic lines come out the side. The compartment walls separate the hydraulics from the exhaust gas should the exhaust pipe fail.

The underfloor areas next to the nose wheel well were not protected due to its inaccessibility and the low probability of the existence of conditions necessary for combustion.

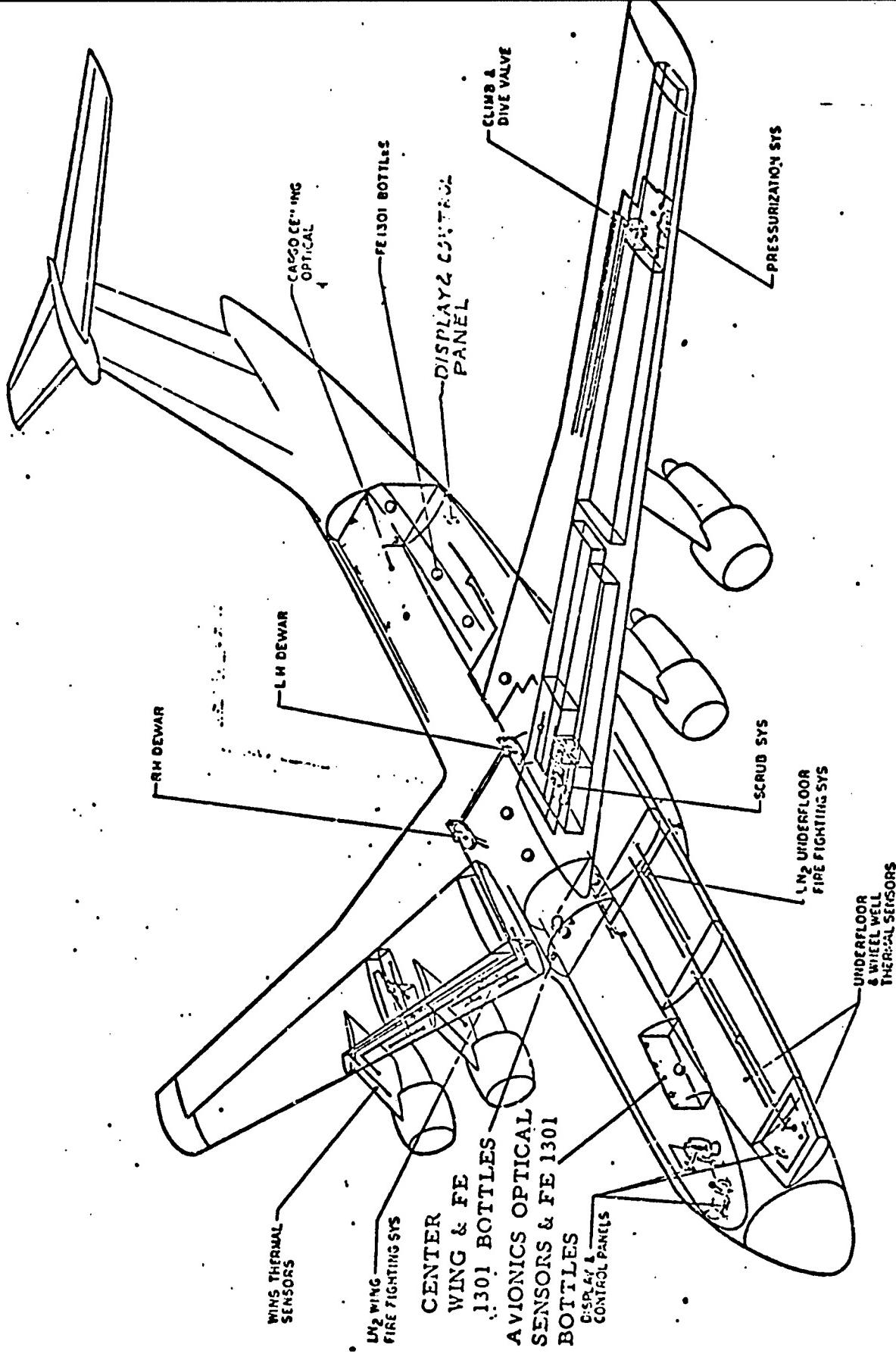
The radome has no flammable fluids in it.

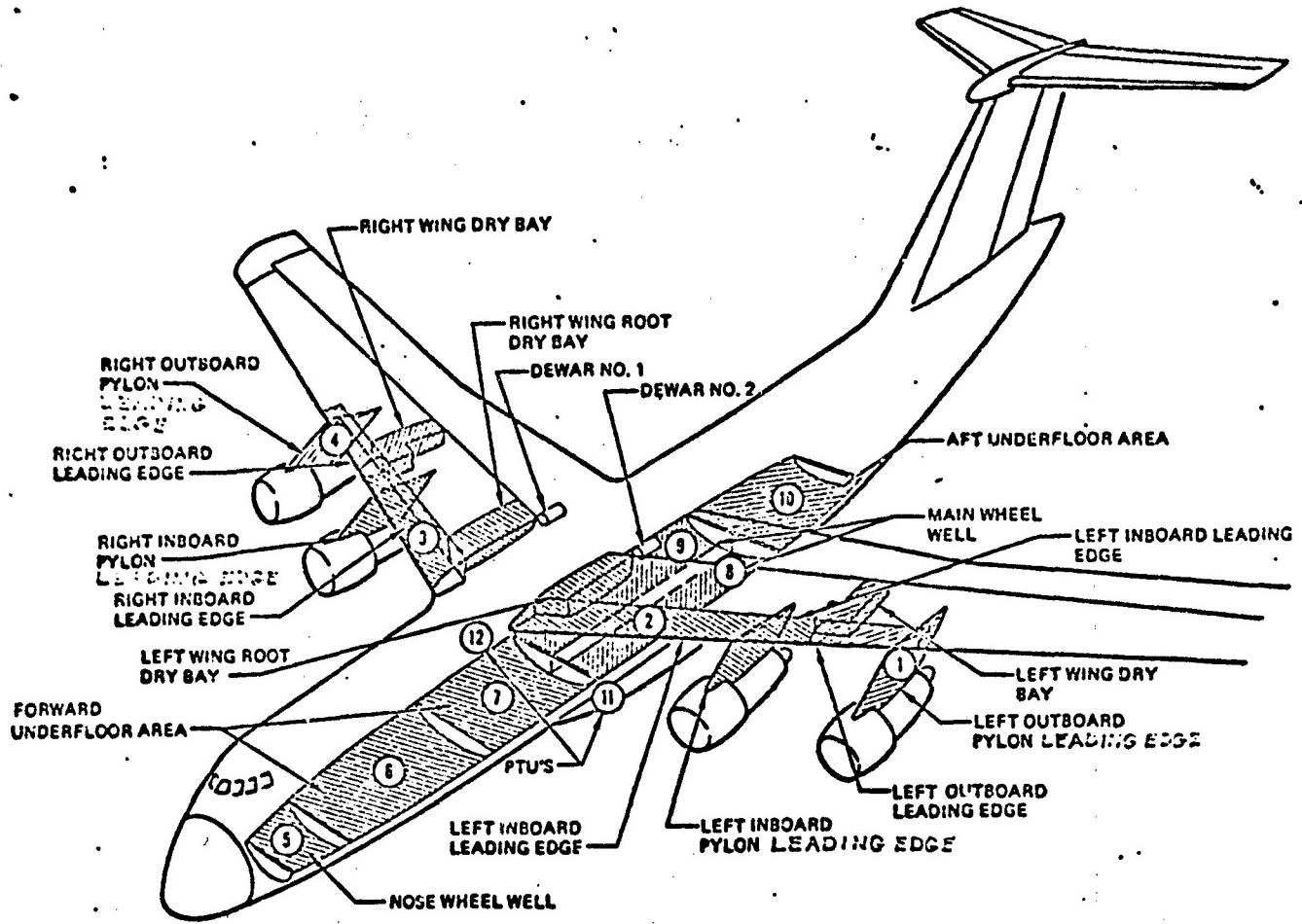
The wing tips are well ventilated and have only a small possibility of having the conditions necessary for combustion.

The wing fairing and under lobe to lobe panel areas are well ventilated. The possibility of getting extinguishing agent to a fire, should one start, is very small. Any flammable fluid would run out of the area rather swiftly. This with the ventilation, greatly decrease the chance of combustion.

The wing leading edge outboard of No. 1 and No. 4 engines has no hydraulic fluid and the only fuel would be JP-4 leakage through the front spar. There are few potential ignition sources.

On all areas that were not protected by the FSS, the decisions not to protect them were based on weighing the probability of combustion occurring against the ability to get enough agent to the fire to extinguish it, the ability to install the fire fighting capability, and the weight increase.

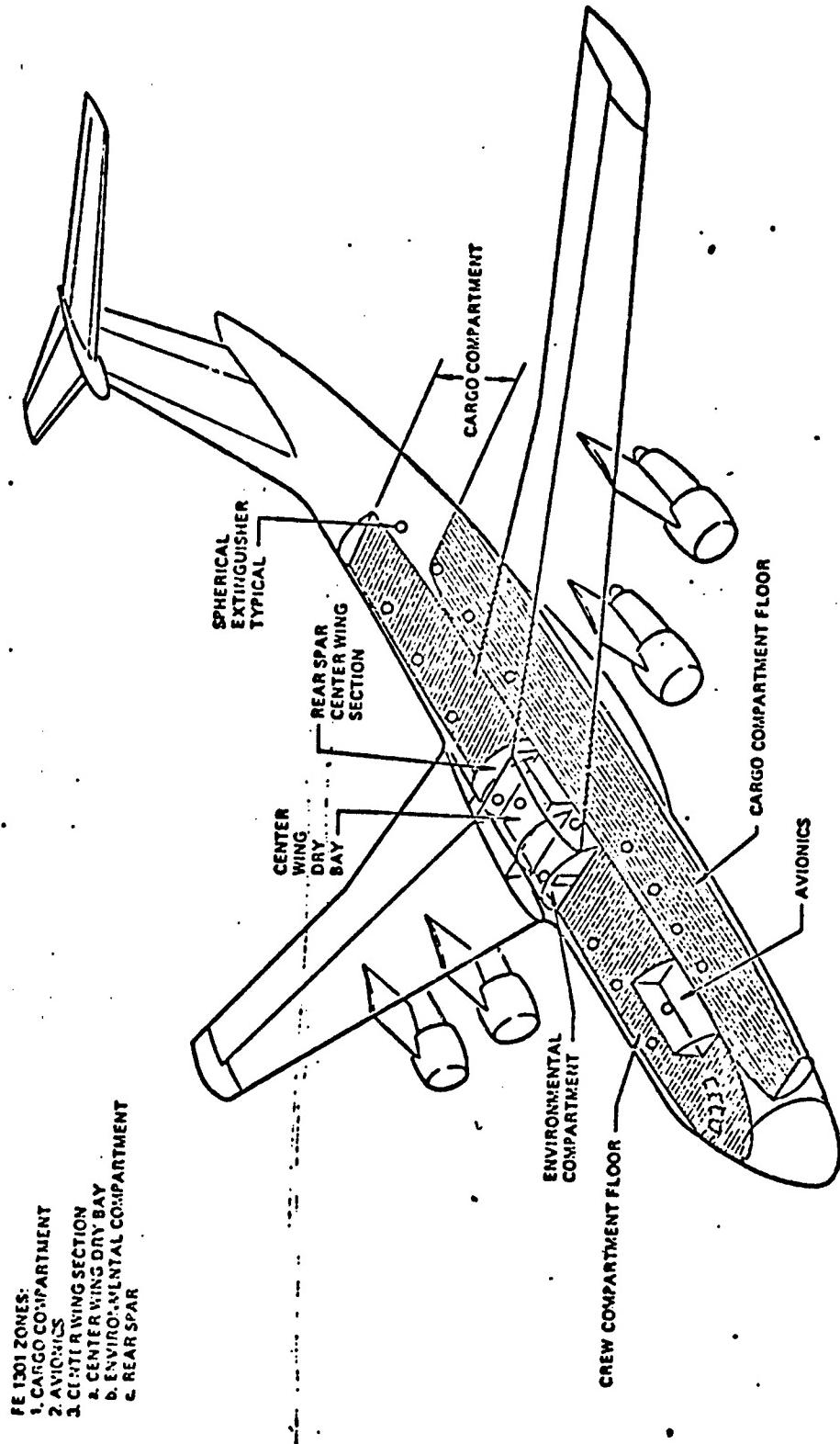




(CIRCLED NUMBERS IDENTIFY EACH ZONE)
ZONE 11 & 12 ARE IN THE FORWARD
AREA OF THE PTU'S

NITROGEN FIRE SUPPRESSION ZONES AND CONTROLS

LOCATIONS OF FE 1301 FIRE FIGHTING ZONES



STIMSON 43 FT LONG 160°
7720057-101

ZONE 9
R MAIN WHEEL WELL

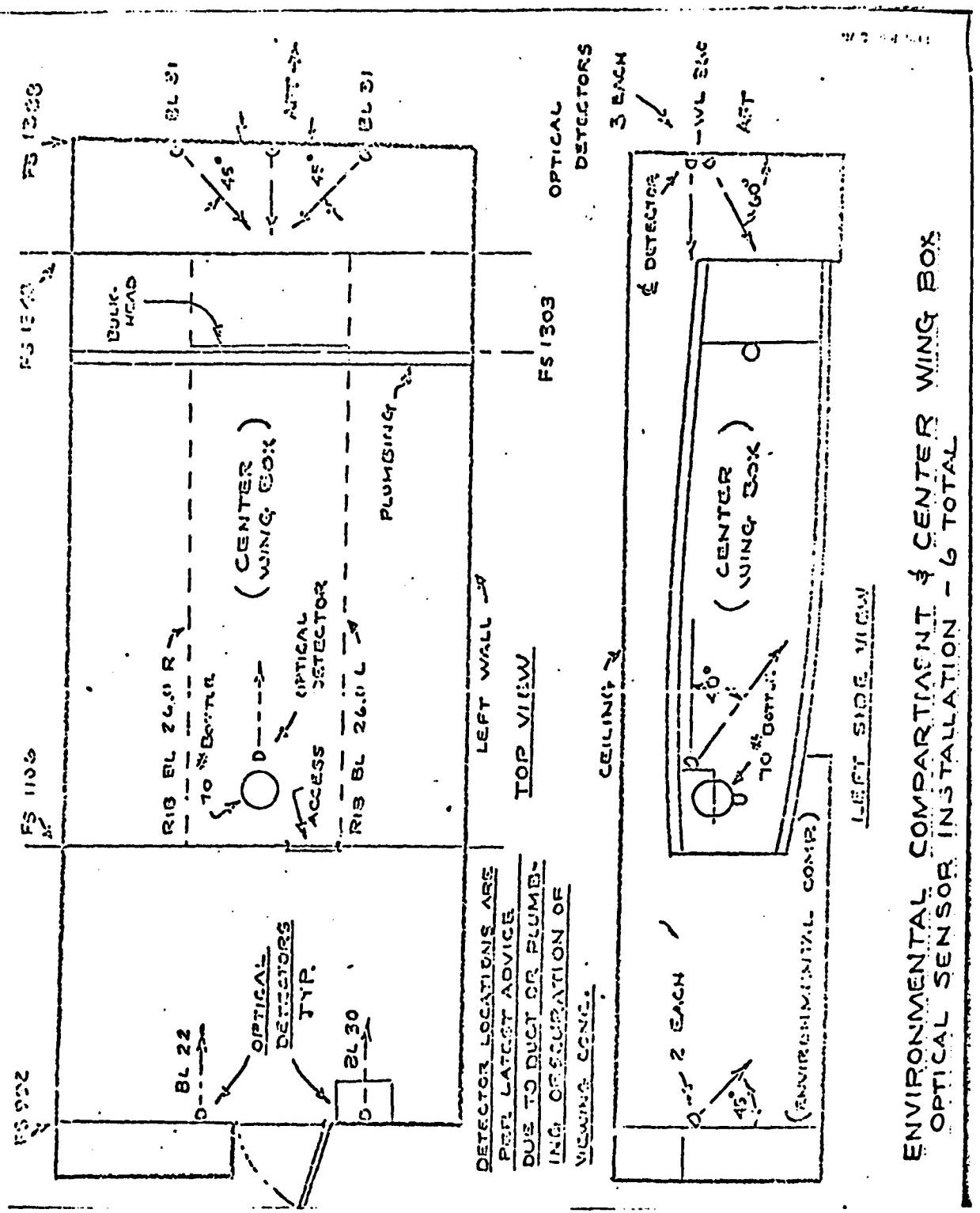
ATM
CONTROL
PANEL

TOP OF
FOREW'D
TWO
WHEELS
TYR.

REAR SECTION OF
AFT FOUR WHEELS, TYR

ZONE 8
L MAIN WHEEL WELL

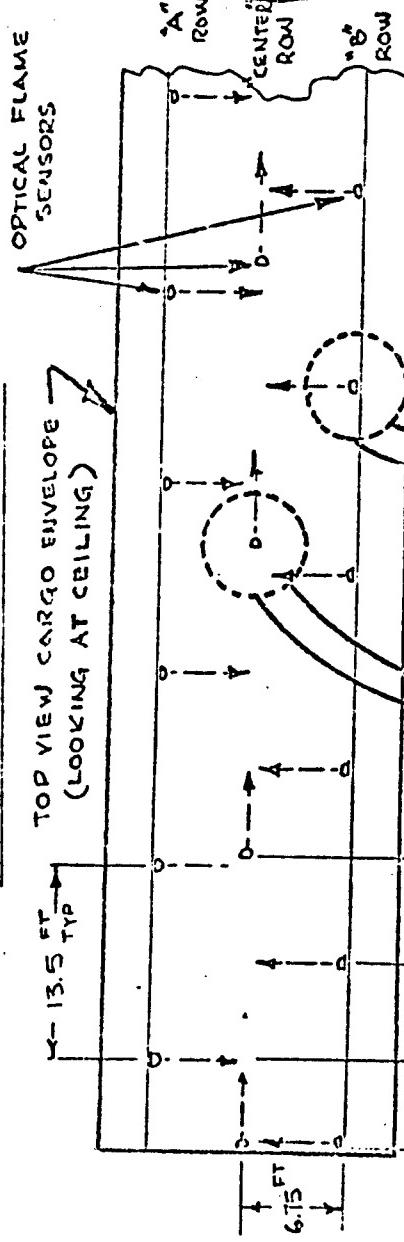
SENSOR 43 FT LONG 160°
7720057-101



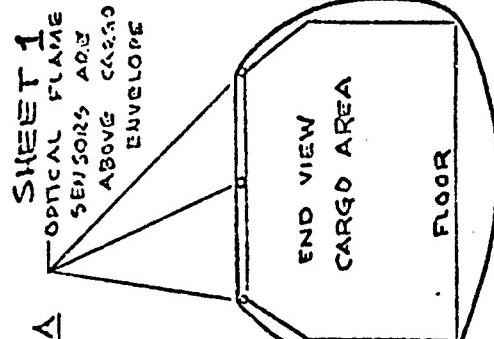
**ENVIRONMENTAL COMPARTMENT CENTER WING BOX
OPTICAL SENSOR INSTALLATION - 6 TOTAL**

OPTICAL FLAME SENSORS FOR CARGO AREA C - 5A

INSTALLATION METHOD

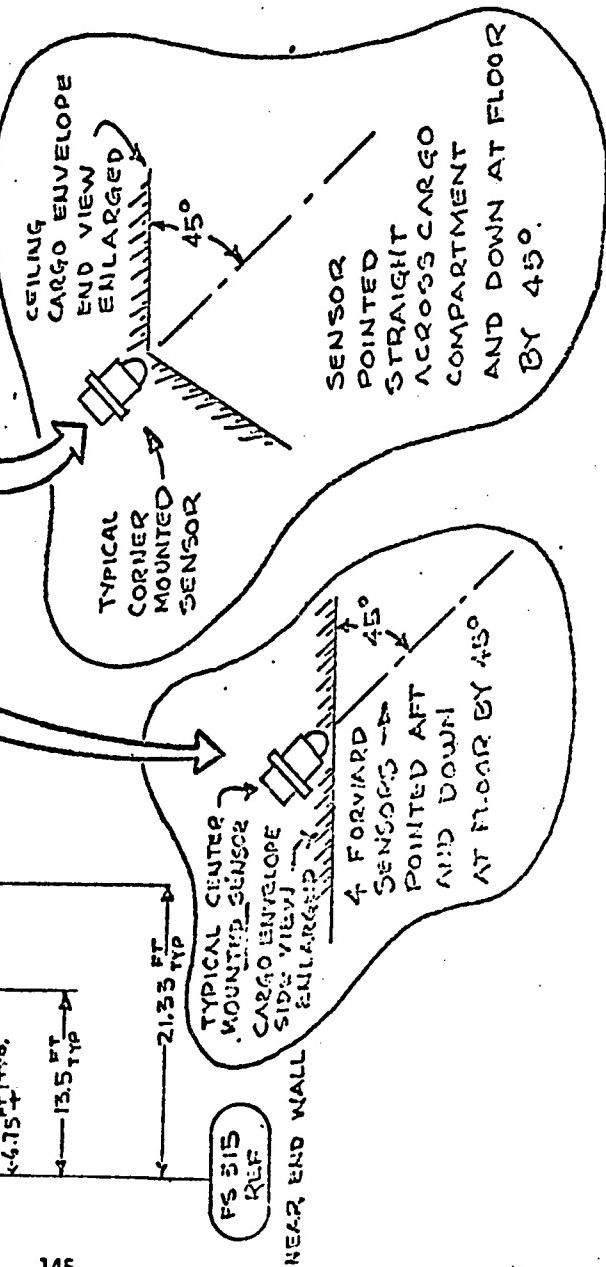


145



CARGO AREA CEILING
15.4 FT X 13.5 FT
30 SENSORS USED IN CARGO
AREA FOR CLOSED DOOR
FIRE DETECTION
"A" ROW USES 11 SENSORS
"B" ROW USES 7 SENSORS*

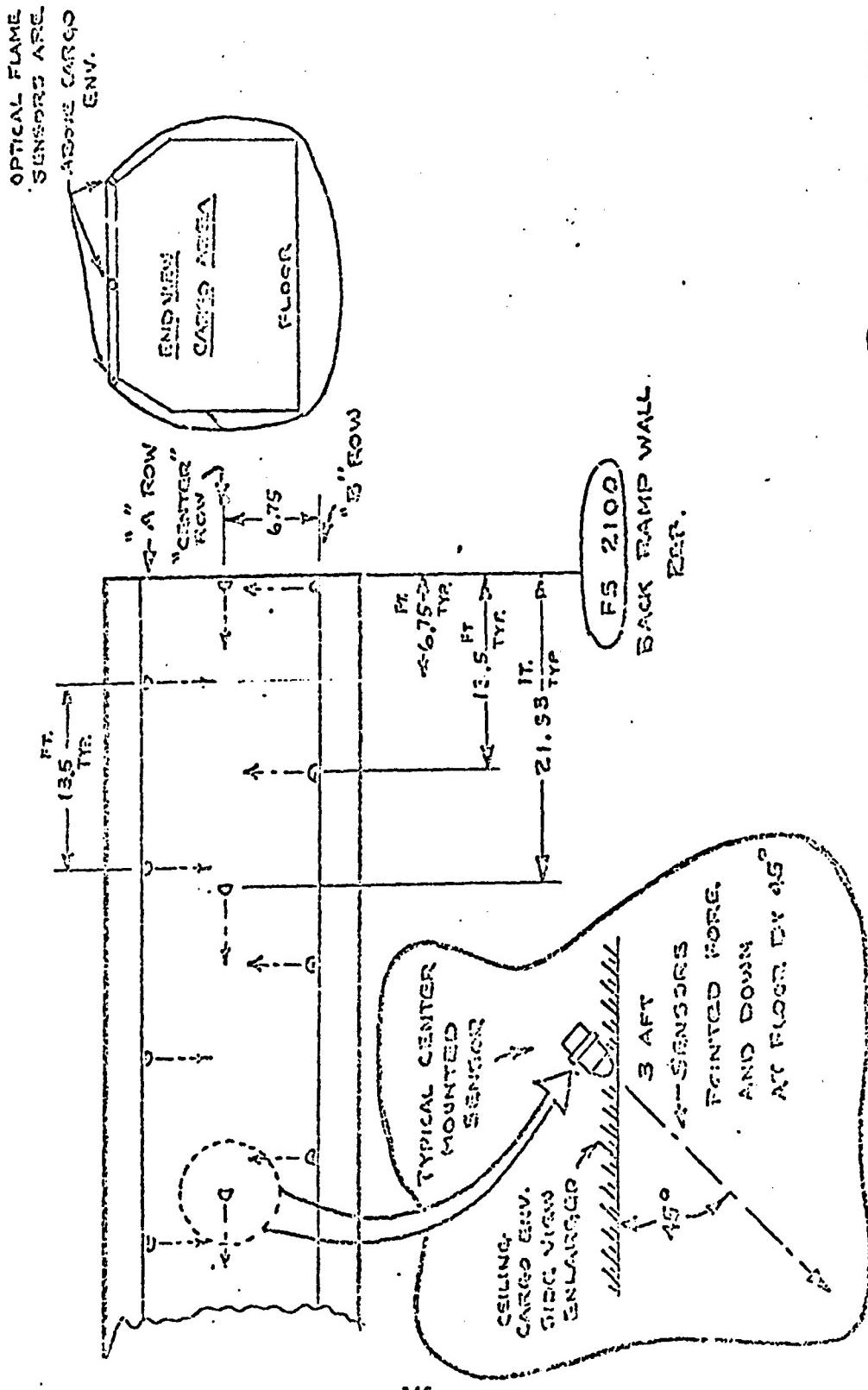
*SEE SHEET 2 FOR
MOUNTING DETAILS
OF THE 3 AFT
CLINCH 2 ROW SENSORS



SHEET - 2

OPTICAL FLAME
SENSEORS FOR CARGO AREA C-5A

INTERVALS AND METHODS



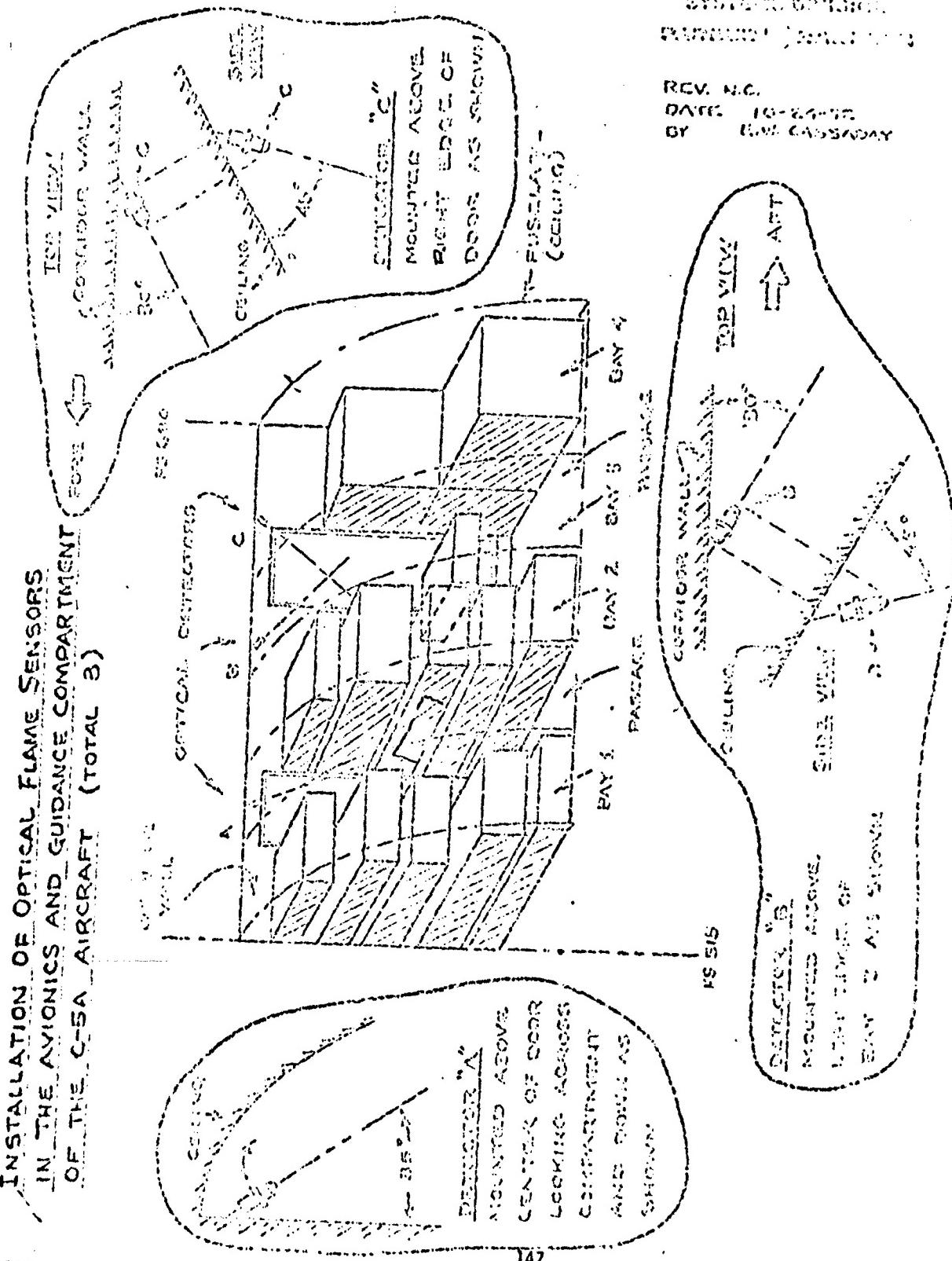
PATRIOT - HANNIBAL
SYSTEMS DIVISION
CITY 16, 1971, 2000

**INSTALLATION OF OPTICAL FLAME SENSORS
IN THE AVIONICS AND GUIDANCE COMPARTMENT
OF THE C-5A AIRCRAFT (TOTAL 3)**

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best available copy.

SYSTEMIC OPTIMISM

REV. N.C.
DATE 10-24-72
BY ERIC CASSIDAY



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DATE

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